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THE ARMOUR ENGINEER begins its second year with the confidence that it has made a good start toward fulfilling the purposes for which it is intended—namely: to be a record of the progress attained at Armour and of the things her graduates are accomplishing, and, what is equally important, to act as a medium through which the students may learn something of the work done by those who have gone before. The reception accorded it by the students and alumni on both occasions of its appearance last year bodes well for the future, and we feel that the high standard of excellence of THE ARMOUR ENGINEER is appreciated by its readers. We wish to thank our contributors for their efforts and for the interest which they have shown, and we hope for the continued support of all loyal sons of Armour.

Members of the alumni are invited to send articles and information concerning their fields of work that will be of interest to our readers.

The Course In Fire Protection Engineering. It has only been within very recent years that any definite and well planned work has been carried out for the purpose of reducing the enormous losses that occur by fire every year in nearly all branches of industry. Previous to this time, the construction of a new building, or the arrangement of apparatus in it for the carrying on of an industry, was governed entirely by the immediate requirements of that industry, and little or no attention was paid to the fire hazard that was involved. The result was a very high rate of insurance and a constant risk of a conflagration. The profitableness of an investment in safeguards against fire gradually became evident however, not only because of the large reduction in insurance rates and the elimination of a great part of the danger, but also because of the fact that the mere recovery of insurance after a fire will only compensate to a small extent for the delays and indirect losses involved, and that the effects of a fire last mentioned are best insured against by adequate means of protection applied in an intelligent manner.

As the number of appliances and methods for fire prevention increased, the problem of adjusting the insurance rates became exceedingly intricate and complex, and it came to be recognized that men of considerable education were needed in this field. In answer to the demand for such men, many eastern and a number of the western schools established courses in fire insurance, treating of this próblem from the standpoint of the insurance company that was assuming a hazard. Such courses were comparatively short however, and were in some cases included as side line in a major course or placed in the curriculum of an evening school.

It remained for the Armour Institute of Technology to get down to the fundamentals of the problem and establish a course in Fire Protection Engineering. As the name of the course implies, it is not only designed for the study of the adjustment of fire insurance rates, but what is more important, but for the intelligent study of practical protective devices for hazards already in existence and of new protective measures applicable to hazards still to be constructed. The student in

the Fire Protection Engineering Department is given four years of training in this branch of engineering in much the same manner as are the students of the other branches, and this course is the only one of its kind in existence. Furthermore, the course leads to a bachelor's degree, placing it on the same plane with the other engineering courses that are taught at the school.

The young man who is about to enter upon his college career should consider well the opportunities afforded by this new field of engineering activity before deciding upon the line of study that he will take up. Although the work in Fire Protection Engineering is of so recent origin, the rapid strides towards success made by those who have already graduated in this course show that the success of men engaged in this profession is an assured quantity, and that the beginner need have no fear as to the outcome of graduating as a Fire Protection Engineer. Such engineers, having the ability to deal intelligently with the application of modern fire protection, are in demand by many manufacturers protective devices as well as by the fire insurance companies. In addition, there is a still undeveloped field for these men as municipal experts for fire and building departments in large cities.

The establishment of the course in Fire Protection Engineering at the Armour Institute of Technology has placed it in a unique position, and one that it will be hard for any other school to emulate. The Underwriter's Laboratories, established by the united insurance companies of the country, are at the disposal of the student, and much of his time during the last two years of study is occupied by work in them. The best facilities for research work in all lines of fire protection are here open to him, giving ample opportunity for the exercise of his originality. Then there are the engineering laboratories of the Institute which are also open to him, giving opportunity to investigate the ordinary engineering methods and appliances. Besides this, the location of the Institute in so large a city gives the student an opportunity to investigate numerous hazards of every description, and the effects of a fire can often be studied while it is in progress. It will thus

be seen that the opportunities for study in this branch of the engineering profession by the students of the Armour Institute of Technology cannot be equaled at any other educational institution.

The importance of the problem of fire prevention is seldom realized, and the average person of the present day has little or no conception of the extent to which the wealth of this country is reduced by the annual fire loss. Elsewhere in this issue will be found a very able treatment of "The National Fire Loss," by Prof. Joseph B. Finnegan, Associate Professor of Fire Protection Engineering of the Armour Institute of Technology, in which the growing importance of this subject is brought out. His comparison of the United States with the nations of Europe in the matter of fire loss is positively startling, and it is high time that the public mind should be awakened to the real conditions that now exist. The conclusions drawn by Prof. Finnegan in his last paragraph are very pertinent, and present a subject in which the entire population of the nation should be better educated.

Track Elevation In Large Cities. In obtaining their right of way through the average American city, the railroads generally begin while the city is quite small, and in most cases the grade of the road is the same as that of the streets. With the enormous rate of growth that is extant in the cities of this country, however, it does not take many years before trouble begins to develop from the existence of grade crossings, and when this happens, the operation of the road is generally hampered by enactments of the municipal governing bodies, restricting the speed of trains, their length, etc. In addition to this, there are a large number of accidents taking place at these crossings which cannot be avoided, making the railroad liable to heavy damage suits. This condition of affairs has brought about the separation of the street and railroad grades in many cities, the most notable of these being our own city of Chicago. Though the separation of the grades was at first looked upon as a hardship by the railroads, and was in many instances fought by them, it has been found that there

are many desirable advantages accruing from the expenditures made in this manner. Trains can be run at a greater speed and with more regularity, the expense of keeping crossing gates and watchmen is eliminated, and the number of damage and personal injury suits is brought down to a minimum.

The city of Chicago stands out as the pioneer in grade separation, the first work of any note being completed in 1892, although a small piece of track elevation was completed in 1888. From that time on, there has always been some piece of track elevation work in progress in this city, until now, the greater part of the railroad trackage within its limits is either elevated above or depressed below the level of the city's streets. Among other cities in which the railroad and street grades have been separated are, Boston, Mass., Brockton, Mass., Newark, N. J., and Pittsburg, Pa. In none of these cities, however, has the work been gone into as extensively as in Chicago.

The separation of track and street levels is of two kinds, the elevation of the tracks above the streets, and the depression of the tracks below the streets. The system of depressing the tracks is little used, however, the most notable instance of this kind being the work done in the city of Milwaukee, Wis. Track elevation is looked upon with far more favor, and has been used almost exclusively in Chicago. From 1892 to the present date, nearly 200 miles of main track, or about 900 miles of single track have been elevated in this city, and over 600 subways have been put in for the street crossings, the entire expense coming to about $50,000,000. From the above statement it will be seen that Chicago's track elevation has grown to be a matter of considerable importance, the sum spent for this work being many times greater than that spent in any other city for a similar purpose.

The outlay of this enormous amount of money has brought about the organization and perfection of large engineering forces. On another page will be found a description of "The Evanston Track Elevation" by Mr. E. O. Greifenhagen, who is a member of the engineering force of the Chicago, Milwau-

kee and St. Paul Railroad. In this description, he has gone into considerable detail as to the manner in which the work is prosecuted, and it will at once be evident to the reader that the engineering problems involved are of no small order. Not only must the problems arising from the elevation work itself be met and solved, but the work must be so conducted as not to interfere seriously with the running of trains over the road. Mr. Greifenhagen's treatment of this particular piece of track elevation is a valuable addition to the literature on the subject because of its analytical nature, and it is published in full so as to give the reader the benefit of the things that are there brought out.

EVANSTON TRACK ELEVATION, CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

BY E. O. GREIFENHAGEN, C. E.*

The Bridge and Building Department of the Chicago, Milwaukee & St. Paul Railway Company, under the direction of Mr. C. F. Loweth, engineer and superintendent, is completing some interesting construction work in connection with grade separation in Evanston, Illinois. The work presented a number of difficult problems and a description of the solutions proposed and of those adopted, together with a discussion of the reasons for the choice made, will probably be of interest.

The City of Evanston extends about four miles along the shore of Lake Michigan just north of the city limits of Chicago. It has a population of nearly 30,000 and is almost exclusively a residence town; its inhabitants go to Chicago for their shopping, amusements and daily vocations. The Chicago and Evanston Division of the Chicago, Milwaukee & St. Paul Railway runs from the Union Depot, Chicago, northward through the North Shore suburbs of the city, through Evanston and into the town of Wilmette, just north of Evanston, a total distance of about fourteen miles. This line handles a considerable freight traffic from the north branch of the Chicago River and some from Evanston, and formerly took care of a certain amount of suburban passenger traffic along the North Shore. The Chicago terminal of the C., M. & St. P. Railway is, however, not very convenient to the main business, shopping and theater center which lies within the "Union Loop" made by the elevated railroads of the city.

The Northwestern Elevated Railroad originally extended from the Union Loop to Wilson Avenue, a distance of 6.5 miles, and its terminal was at Wilson Avenue Station on the line of the Chicago and Evanston Division of the C., M. & St. P. Railway, as shown on the accompanying map, Fig. (1). The Northwestern Elevated had long desired an extension to Evanston and the growing suburbs north, and in August, 1907, it obtained a lease from the C., M. & St. P. Railway which allowed it to run its trains on the latter company's right of way from Wilson Avenue to Central Street, a distance of 7.2 miles. This part of the St. Paul line was modified for electric traffic, and on May 16, 1908, trains were run from the Union Loop to the

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*Class 1906. Office Engineer, Bridge and Building Department, Chicago, Milwaukee & St. Paul Railway.

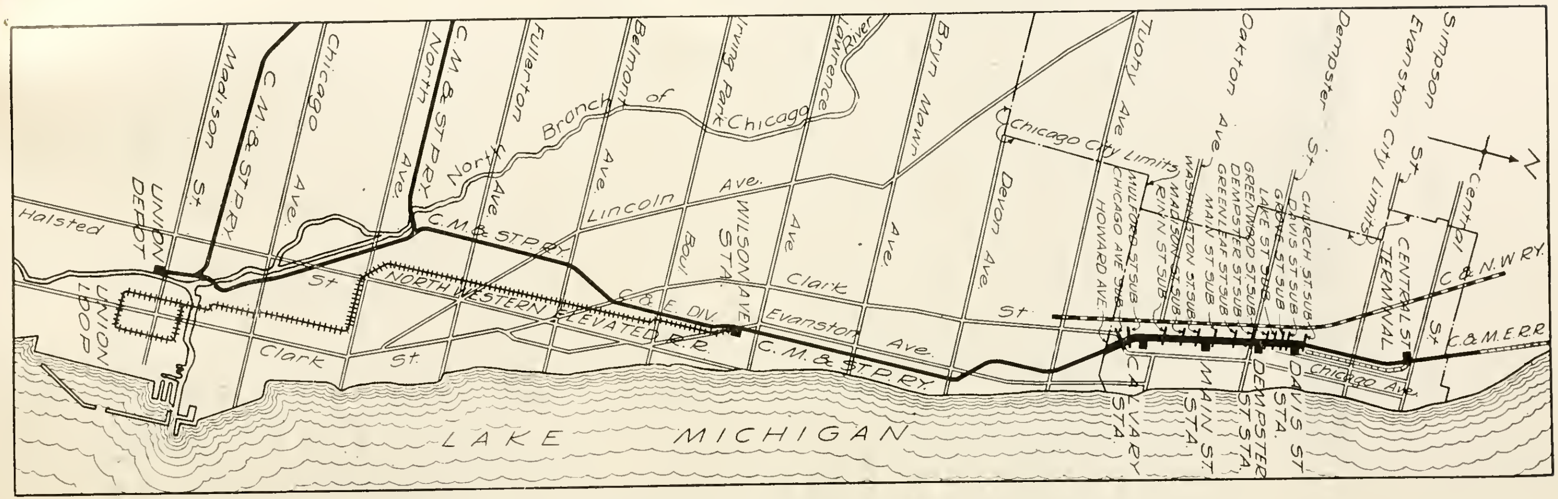

Fig. 1. "Map Showing Route of Chicago & Evanston Division, C., M. & St. P. Ry."

north end of Evanston, a distance of about 13.7 miles. The St. Paul tracks north of Central Street are used by the Chicago & Milwaukee Electric Railroad, which parallels the Northwestern Elevated down to Church Street.

It will be seen from the map, Fig. (1), that the right of way of the Chicago & Northwestern Railway adjoins that of the Chicago, Milwaukee & St. Paul Railway from a point near the southern boundary of Evanston to Davis Street, which is one block south of the limit of the track elevation. The very heavy traffic on the Chicago & Northwestern Railway Company's line and the frequency of the electric trains on the St. Paul Company's tracks made it difficult to prevent accidents at the numerous street crossings. The unusual condition brought about by the proximity of the railways led the city and the two railway companies to agree upon grade separation. An ordinance was passed in March, 1907, by the general terms of which the Chicago, Milwaukee & St. Paul Railway Company was required to elevate its tracks for that part of the line extending from the southern boundary of the city to Church Street, which is at the north end of the business district. According to the ordinance, the top of rail was to be above specified elevations at each subway; "the embankment was to be composed of cinders, slag, sand, clay, gravel, loam, broken stone" or surplus excavated material; and the embankment was to be as wide as desired by the company, provided it were retained within the right of way by suitable walls. The ordinance applied to the Chicago & Northwestern Railway Company was similar.

A description of the engineering work done by the C., M. & St. P. Railway in connection with this grade separation will be given under the following general heads:

Subway Problem.
Design of Subway Bridges.
Construction of Subway Bridges.
Design and Construction of Retaining Walls.
Design and Construction of Stations.
Miscellaneous Work.

SUBWAY PROBLEM.

The bridges which carry the elevated tracks over the streets are, from an engineering standpoint, the most important features of track elevation work, for the reason that they control the elevation of base of rail and consequently the profile of the line, that they furnish the largest separate items of cost in such work, and that they are practically the only features of the work which are constantly before the eyes of the public and which affect the public most directly. These three matters were considered when the question of the type of

structure for the Evanston subways was taken up, and it was endeavored to design bridges which would have, (1) floors as thin as practicable, to make the elevation of the tracks a minimum; (2) initial costs as small as possible consistent with durability and economy in maintenance, and (3) a good appearance and qualities which would render them noiseless and as nearly waterproof as possible.

That part of the ordinance referring most directly to the construction of the subway bridges, reads as follows:

"........ suitable bridges of one or more spans, the superstructure of which shall consist of iron or steel girders with a continuous floor. Provisions shall be made to prevent storm water, dirt, oil and other substances from dropping from such elevated structure into the subways beneath. The said bridges shall be supported upon abutments of concrete, stone or brick masonry, or on rows of iron or steel columns, braced together laterally, and erected on and anchored to masonry foundations constructed within the lines of the railway company's right of way, and in the centers and curb lines of the intersecting avenues and streets, as provided in schedule of subways herein contained. Provided," etc.

This clause referring to the type of subway bridge was considered rather vague, and inserted more for the purpose of eliminating wooden or temporary constructions and non-continuous floors than for the purpose of binding the railway company to any particular design, and consequently it was decided to estimate on various types of steel, reinforced concrete and combination bridges, which might fit the conditions and comply with the spirit of the ordinance.

The essential features of the fourteen crossings included in the "Schedule of Subways" of the original ordinance are given in the following table:

SCHEDULE OF SUBWAYS—FIRST ORDINANCE.

Name of Subway	Total Width between Abutments	Width of S. Sidewalk	Width of Roadway	No. of Roadway Spans	Width of N. Sidewalk	Headroom	Skew
Howard Ave.	56′ 0″	10′ 0″	36′ 0″	1	10′ 0″	12′ 0″	
Chicago Ave.	56′ 0″	10′ 0″	23′ 0″ & 23′ 0″	2	......	13′ 0″	18° 38′
Mulford St.	34′ 0″	5′ 0″	24′ 0″	1	5′ 0″	12′ 0″	17° 40′
Rinn St.	48′ 0″	7′ 0″	34′ 0″	1	7′ 0″	12′ 0″	8° 29′
Madison St.	50′ 0″	8′ 0″	34′ 0″	1	8′ 0″	13′ 0″	10° 00′
Washington St.	46′ 0″	8′ 0″	30′ 0″	1	8′ 0″	12′ 0″	10° 20′
Main St.	66′ 0″	10′ 0″	23′ 0″ & 23′ 0″	2	10′ 0″	12′ 0″	21° 13′
Greenleaf St.	46′ 0″	7′ 0″	32′ 0″	1	7′ 0″	12′ 0″	10° 36′
Dempster St.	66′ 0″	10′ 0″	23′ 0″ & 23′ 0″	2	10′ 0″	12′ 0″	8° 28′
Greenwood St.	56′ 0″	10′ 0″	36′ 0″	1	10′ 0″	12′ 0″	11° 53′
Lake St.	52′ 0″	10′ 0″	32′ 0″	1	10′ 0″	12′ 0″	15° 19′
Grove St.	66′ 0″	10′ 0″	23′ 0″ & 23′ 0″	2	10′ 0″	13′ 0″	20° 38′
Davis St.	80′ 0″	14′ 0″	26′ 0″ & 26′ 0″	2	14′ 0″	12′ 0″	8° 28′
Church St.	66′ 0″	10′ 0″	23′ 0″ & 23′ 0″	2	10′ 0″	13′ 0″	0° 02′

It will be seen from an examination of this table that the fourteen subways come under two general classes:

Class A—Seven subways whose greatest span is 26′ 0″ or less. All but one of these subways have the roadway divided into two spans by a pier in the middle of the street.

Class B—Seven subways whose greatest spans vary from about 30 feet to about 36 feet. None of these subways have piers in the middle of the roadway.

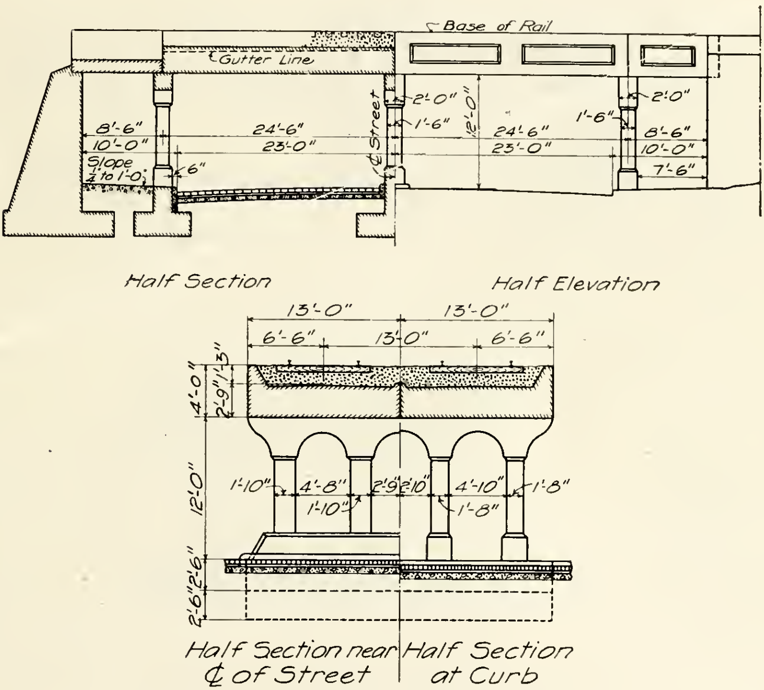

FIG. 2. PART 1—PROPOSED SCHEME A-1

In making the preliminary estimates these two classes were considered separately, because structures that were satisfactory for one class were not necessarily best for the other class on account of the difference in length of span. As representing the class "A" subways, Grove Street was chosen, which was to have two sidewalks 10′ 0″ wide and a 46′ 0″ roadway, with piers allowed at the curb lines and at the middle of the street, making a four-span crossing. As representing class "B" subways, Greenwood Street was chosen, which was to have sidewalks 10′ 0″ wide and a 36′ 0″ roadway, with piers allowed at the curb lines only, making a three-span bridge.

There were five schemes drawn up and estimated for the Grove Street subway, as follows:

Scheme A-1. Reinforced concrete slabs, 13 feet 0 inches wide, supported by reinforced concrete piers, each pier having four columns. (See Fig. 2, Part 1.)

Scheme A-2. I-beam deck spans (eight 20-inch I-beams per track for roadway spans) with a reinforced concrete bal-

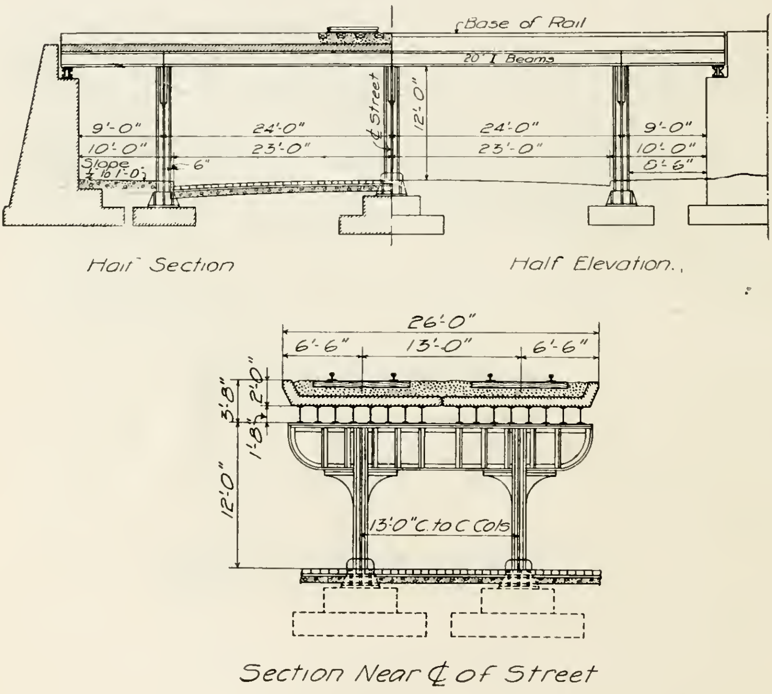

Fig. 2. Part 2—Proposed Scheme A-2

last deck supported by structural steel bents or piers of two columns per bent. (See Fig. 2, Part 2.)

Scheme A-3. I-beam deck spans (four 24-inch I-beams per track for roadway spans) with solid reinforced concrete ballast deck and ornamental reinforced concrete parapets or facia girders, supported by structual steel bents or piers of two columns per bent.

Scheme A-4. Through plate girder spans with solid floor composed of 15-inch I-beams spaced about 18 inches center to center and covered with a solid reinforced concrete ballast deck; girders supported by structural steel bents or piers of three columns per bent.

Scheme A-5. Through plate girder spans with I-beam floor, similar in design to scheme A-3, except that the curb

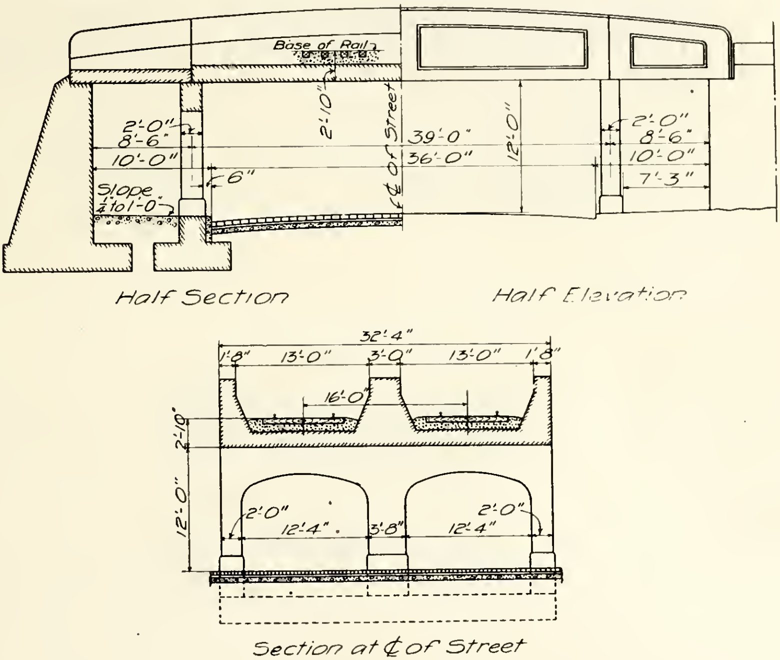

Fig. 2. Part 3—Proposed Scheme B-1

piers are omitted and the girders span from the abutments to the middle pier.

There were six designs drawn up and estimated for the Greenwood Street Subway, as follows:

Scheme B-1. Reinforced concrete through girder bridge composed of heavy reinforced concrete girders, with a solid continuous concrete ballast floor spanning between them, supported by reinforced concrete piers, each pier having three columns. (See Fig. 2, Part 3.)

Scheme B-2. Through plate girder spans with I-beam floor composed of 12-inch I-beams spaced 15 inches center to center with a continuous reinforced concrete ballast deck; girders supported by structural steel bents or piers of three columns per bent. (See Fig. 2, Part 4.)

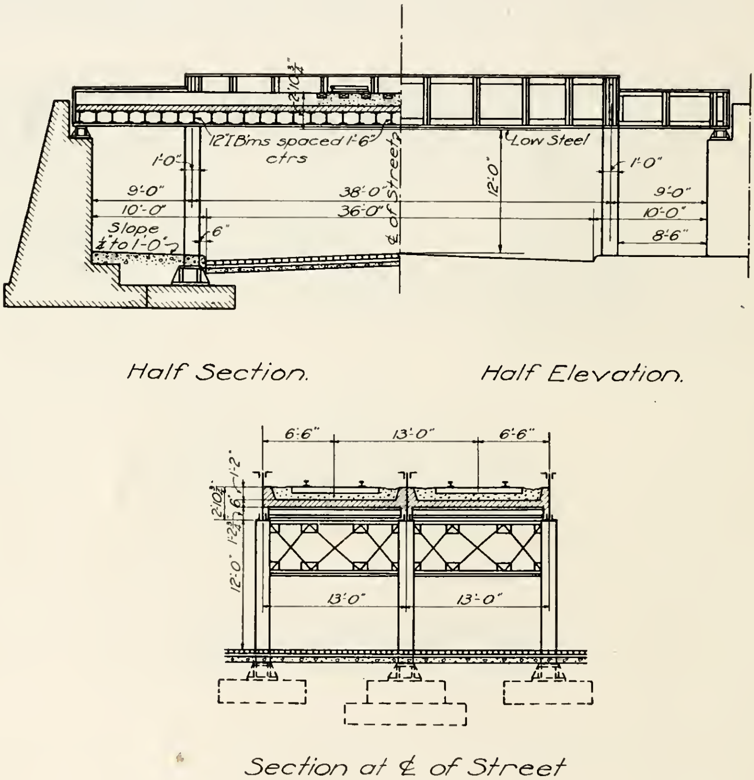

Fig. 2. Part 4—Proposed Scheme B-2

Scheme B-3. Through plate girder spans with regular steel cross floorbeams and stringer floor system, with a continuous reinforced concrete ballast deck; girders supported by structural steel bents or piers of three columns per bent.

Scheme B-4. Bethlehem girder beam deck span (six 26-inch beams per track for roadway spans) with a reinforced concrete ballast deck, supported by structural steel bents or piers of two columns per bent. (See Fig. 2, Part 5.)

Scheme B-5. Similar to scheme B-4 except for the addition of ornamental concrete parapets or facia girders.

Scheme B-6. Span made up of two 30-inch Bethlehem girder beams per rail; rails set down between pairs of beams and supported by a concrete floor; spans supported by structural steel bents or piers of two columns per bent. This scheme has since been used by the C., B. & Q. Railway Company on track elevation work.

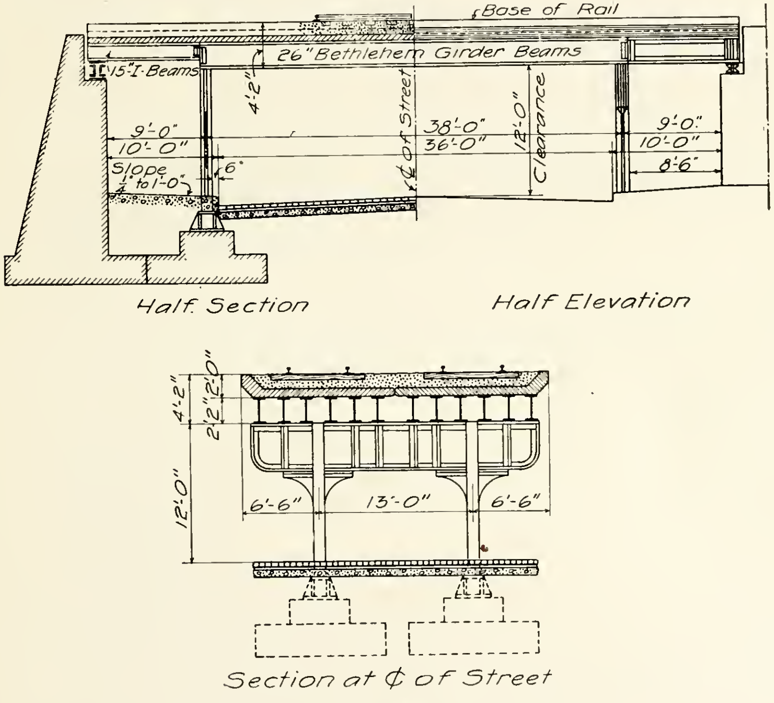

Fig. 2. Part 5—Proposed Scheme B-4

All the above schemes were estimated for a double track bridge exclusive of track, abutments, falsework, depression of street, paving and all other items which were common to every type considered, and which, therefore, would not affect their relative costs. Natural foundations were assumed in all cases. It was found that pile foundations would add about 10 per cent to the estimates. The following table shows the relative costs and depths from base of rail to low bridge for each structure estimated; the cost of scheme A-1, being the lowest, is called 100.

Scheme	Depth of floor	Cost
A—1	4′— 0 ″	100
A—2	3′— 8 ″	112
A—3	4′— 0 ″	108
A—4	3′— 5½″	146
A—5	3′— 5½″	149
B—1	2′—10 ″	104
B—2	2′—10¾″	150
B—3	3′— 9½″	134
B—4	4′— 2 ″	134
B—5	4′— 2 ″	136
B—6	2′— 0 ″	132

The depths of the floors for the schemes are second only to the first cost of the bridge in their bearing on the total cost of the track elevation work, and they were fully considered in the choice of the final types. A list of advantages and disadvantages of each of the schemes was also studied in connection with the data given in the above table, and as the result of the investigation, it was decided to eliminate schemes A-3, A-4, A-5, B-3, B-5 and B-6. A summary of the reasons for eliminating these schemes may be of interest. Scheme A-3 was considered a less satisfactory design than scheme A-2 because of its greater depth and because the permanence of the false concrete facia girders under the action of deflection and vibration was questioned. Schemes A-4, A-5 and B-3 were discarded because their heavy first cost was not compensated for by a shallow floor, and because the girders projecting above the track level were considered undesirable. Scheme B-5 was replaced by scheme B-4 in the final estimates because there was little difference in the two designs. Scheme B-6 was ruled out because of its non-continuous floor and because of the unsatisfactory roadbed which it provided.

This left five schemes for final consideration, two schemes for Class A subways and three schemes for Class B subways. The five designs are shown in Fig. 2. Relative costs and depths of floor for the schemes are given below:

Scheme	Depth of floor	Cost
A—1	4′— 0 ″	100
A—2	3′— 8 ″	112
B—1	2′—10 ″	104
B—2	2′—10¾″	150
B—4	4′— 2 ″	134

Since the depth of the floor controlled the gradient of the track and the amount of fill required, it was necessary to figure this effect in dollars and cents before the cheapest combination of schemes for the two classes of crossings could be ascertained. Accordingly, calculations were made to determine the amount of fill and the yardage in retaining walls, as well as the effect on the gradients, for several combinations. The combination of all-concrete bridges, schemes A-1 and B-1, required from 4,500 to 13,000 cubic yards to fill and from 320 to 540 cubic yards of concrete less than any other combination. These facts, together with the figures given in the table of costs, showed conclusively that reinforced concrete bridges for all subways had the least first cost from all points of view. The advantages for the concrete bridges, exclusive of first cost, as compared with the structural steel bridges were tabulated.

Advantages Claimed for Concrete Bridges:

1. Greater economy.
2. Greater rigidity and freedom from vibration; noiseless.
3. Durability; practically permanent.
4. Require almost no maintenance.
5. Of good appearance, as befits bridges in a residence town.
6. Built entirely of the same materials; footings, abutments and piers can be put in by the same forces, with the same plant.
7. All work can be done by the company.

Advantages Claimed for Steel Bridges:

1. The strength of the structure can be definitely determined by a field examination, in case the plans are destroyed.
2. Ordinary errors of workmanship will not affect the stability of the structure.
3. Alterations not impossible.
4. Bridges will always have some salvage value.
5. Ordinance need not be amended, as would probably be the case if concrete superstructures were adopted.
6. A disadvantage of the proposed concrete through girders which steel bridges do not have is that the former require the spreading of the tracks to clear the middle girder.

Taken all in all, it was decided that the concrete bridges would be most desirable, and steps were taken to bring the matter before the Evanston authorities in order to obtain their

approval for reinforced concrete superstructure. At the same time a sentiment developed on the part of the city for wider subways than specified in the schedule of the first ordinance. The railway company had found that the bridges over streets which required long clear spans were more costly per lineal foot than the bridges over wider streets which allowed piers in the middle of the roadway, and also that the former would not permit the use of deck slabs (scheme A-1). Consequently when the city suggested a new schedule of subways including some wider streets with middle piers, the company was inclined to agree to the change.

An amendment to the original ordinance was passed in February, 1909, permitting the use of reinforced concrete bridges and containing the following revised schedule of subways:

SCHEDULE OF SUBWAYS—REVISED ORDINANCE.

Name of Subway	Total Width between Abutments	Width of S. Sidewalk	Width of Roadway	No. of Roadway Spans	Width of N. Sidewalk	Headroom	Skew
Chicago Ave.	60′ 0″	10′ 0″	20′ 0″ & 20′ 0″	2	10′ 0″	13′ 0″	18° 34′
Mulford St.	40′ 0″	10′ 0″	20′ 0″	1	10′ 0″	12′ 0″	17° 40′
Rinn St.	60′ 0″	10′ 0″	20′ 0″ & 20′ 0″	2	10′ 0″	12′ 0″	8° 29′
Madison St.	60′ 0″	10′ 0″	20′ 0″ & 20′ 0″	2	10′ 0″	13′ 0″	10° 0′
Washington St.	60′ 0″	10′ 0″	20′ 0″ & 20′ 0″	2	10′ 0″	12′ 0″	10° 20′
Main St.	66′ 0″	13′ 0″	20′ 0″ & 20′ 0″	2	13′ 0″	12′ 0″	21° 13′
Greenleaf St.	60′ 0″	10′ 0″	20′ 0″ & 20′ 0″	2	10′ 0″	12′ 0″	10° 36′
Dempster St.	66′ 0″	13′ 0″	20′ 0″ & 20′ 0″	2	13′ 0″	12′ 0″	10° 36′
Greenwood St.	66′ 0″	13′ 0″	20′ 0″ & 20′ 0″	2	13′ 0″	12′ 0″	11° 53′
Lake St.	66′ 0″	13′ 0″	20′ 0″ & 20′ 0″	2	13′ 0″	12′ 0″	15° 19′
Grove St.	66′ 0″	13′ 0″	20′ 0″ & 20′ 0″	2	13′ 0″	13′ 0″	20° 38′
Davis St.	80′ 0″	14′ 0″	26′ 0″ & 26′ 0″	2	14′ 0″	12′ 0″	8° 28′
Church St.	68′ 0″	14′ 0″	20 0″ & 20′ 0″	2	14′ 0″	12′ 6″	0° 02′

The new subway bridges had shorter spans throughout than the bridges for which the original estimates were made, and investigation showed that the saving in grade in favor of the concrete bridges was considerably reduced on account of the new conditions, which required slabs throughout. The other advantages of concrete bridges were greatly enhanced, however, because such a type of construction is well adapted to short spans.

THE DESIGN OF SUBWAY BRIDGES.

Before any detailed work on the plans for the subway bridges could be begun, it was necessary to determine two important matters, namely, the live load to be considered and the unit pressure to be allowed on the foundations.

Loading:

The standard loading for permanent work on the C., M. & St. P. Railway east of the Missouri River is Cooper's E-50.

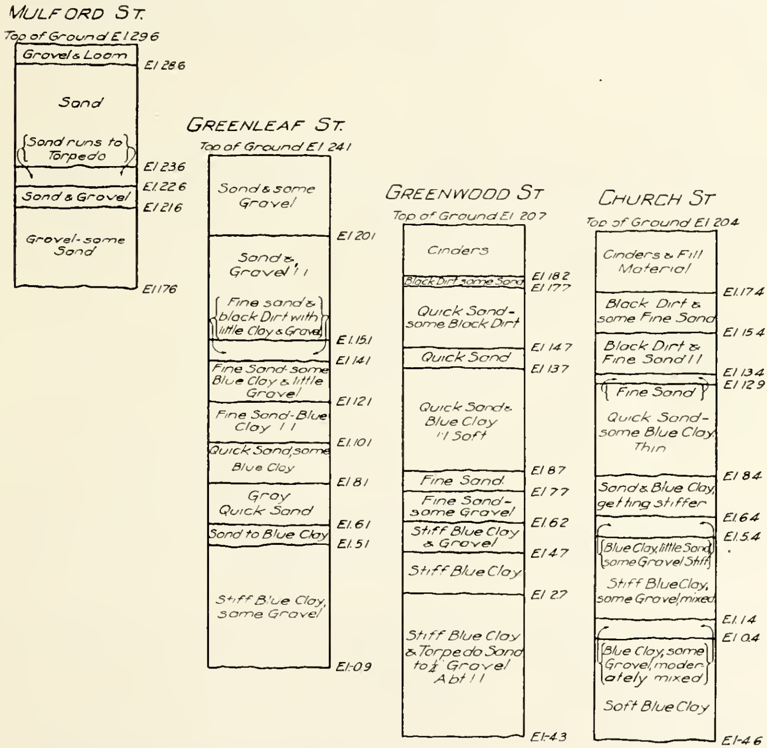

FIG. 3. "TEST PITS AND WASH BORINGS SHOWING CHARACTER OF FOUNDATIONS AT FOUR CROSSINGS."

The question was raised as to whether lighter loading might not be considered on the Evanston Division. On this line the loading consists of electric trains and freight engines, the engines being equivalent to about E-40 loading on spans of 10 to 20 feet. There was a possibility of the future use of electric locomotives for passenger trains. Consequently estimates were made on three types of loading, namely, Cooper's E-50, Cooper's E-40, and a 100-ton electric locomotive similar

to the N. Y. C. & H. R. Railroad type. A typical subway bridge was chosen and the costs for the bridge under these three loadings were estimated to compare as follows:

Cooper's E-50	100
Cooper's E-40	96
100-ton Electric Locomotive	96

An inspection of these relative costs showed that it would be decidedly poor judgment to design such permanent work for light loading, especially when future changes in rolling stock could not be foretold. All work was designed for Cooper's E-50 loading.

Foundations:

In order to determine the conditions existing at the sites of various subway bridges and retaining walls, test pits were dug and wash borings were made at each crossing. The pits were carried down only far enough to ascertain the depth to ground water and the kind and condition of the upper strata. The wash-borings were made to a depth of 50 feet in some cases, a ¾-inch pipe within a 2-inch casing pipe being used. Fig. 3 shows the information obtained from the pits and borings at four crossings. Intermediate pits showed that foundation conditions varied more or less uniformly from one end of the work to the other. On the basis of this information, natural footings were used at 1¾ to 2 tons per square foot for the bridges at Greenleaf Street and all streets south, and pile foundations were used at all points north of this crossing. A bearing on piles of from 12 to 16 tons was allowed. The design of the foundations is described in the paragraphs on piers and abutments.

The question of carrying columns down to bed rock or into firm clay on concrete cylinders was considered, and found to be unwarranted by the conditions.

General Layout:

Fig. 4 shows a half longitudinal section, half side elevation and a cross section of the Chicago Avenue subway bridge as detailed and built. This subway is typical and a description of the bridge at this street will apply to the bridges throughout the track elevation. The subway is on an 18 degree 34 minute skew and has two 10-foot sidewalks and a 40-foot roadway. A middle pier divides the roadway into two channels. Curb piers are allowed within the sidewalk space. The face of the abutments and wing walls is on the street line. A clear head room of 13 feet above the crown of the street is provided, according to the ordinance. The elevation of the sidewalks at

the curb line is the same as that of the crown of the street and the sidewalks are sloped upward toward the abutment at the rate of one-quarter of an inch to the foot.

The requisite massiveness of the bridge, due to the heavy loading and the nature of the material employed, limited the architectural treatment to the simplest lines. The slabs which carry the tracks over the various openings between the abutments and piers are provided with a parapet of uniform depth

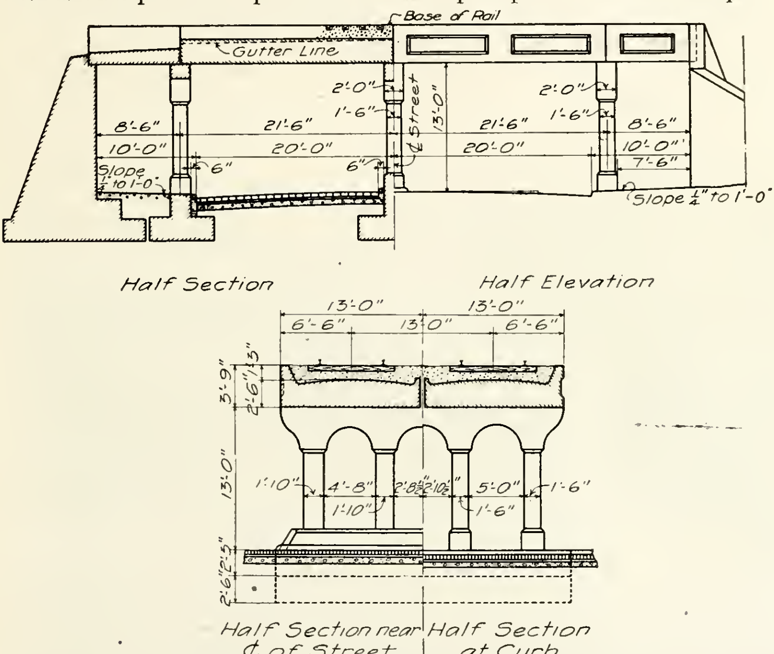

Fig. 4. General Elevation and Sections—Chicago Avenue Subway Bridge.

and width over the entire crossing. The bare surface of this parapet is relieved by simple rectangular recessed panels. The abutments are of heavy construction and give the effect of solidity to the end supports. The composition of the piers was worked out to provide the necessary size of sections and at the same time create an impression of lightness and gracefulness which would relieve any tendency toward a tunnel-like appearance in the subways. The widening of the piers below and above the columns, and the introduction of the curved brackets have an advantage from a structural as well as from an aesthetic standpoint.

The general appearance of the completed subway bridges may be seen from Figs. 5 and 6, which are views at Davis Street and Lake Street respectively.

The detailed description of the design of the bridges will be taken up under the headings "Piers," "Abutments," and "Slabs."

Design of Piers:

There are three piers for each subway, except at Mulford Street, which has only one span over the roadway. The side or curb piers are placed with the outer face six inches behind the curb line, and the middle piers are placed on the center line of the roadway.

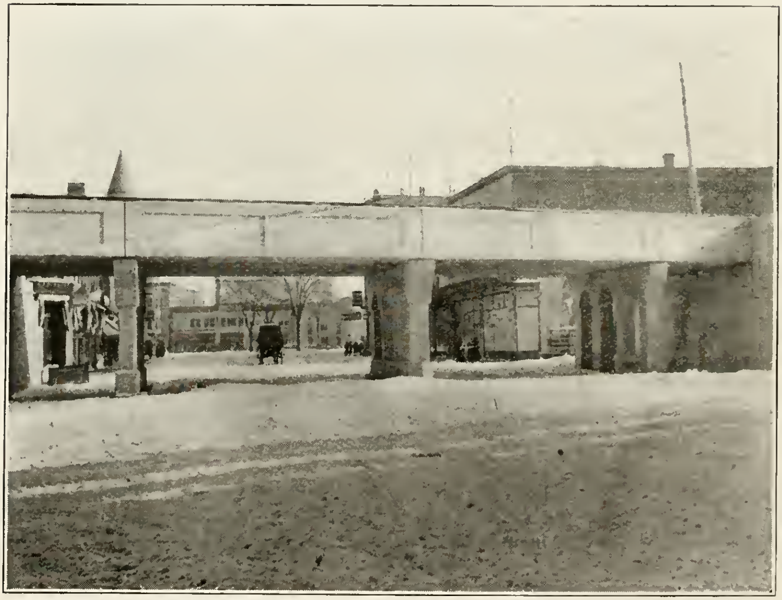

Fig. 5. View of Davis Street Subway Bridge.

The appearance of the piers as constructed may be seen from Fig. 6, which is a view of the Lake Street Subway Bridge. The details of the Chicago Avenue piers are shown on Fig. 7. In general, each pier consists of four columns supporting a cross girder and carried by a footing girder which distributes the load to a footing slab.

The top girder, capping the columns, is given an arched form and figured as a continuous beam. The arches provide curved brackets which stiffen the columns laterally and which

give depth to the beam at the points of greatest shear. There are two 1-inch bars in the top of the girder running the full length of the pier, and an additional pair of 1-inch bars over each column, bent down to assist in taking care of web stresses. There are four 1-inch bars in the bottom of the beam running the full length of the pier. Six to eight ½-inch square stirrups bent in the shape of a "W" are placed in the beams between columns, and three such stirrups in each side cantilever. The curved brackets are reinforced by pairs of 1-inch diagonal bars. The top girders are made six inches wider than the columns; this makes their width 24 inches in all cases except the middle pier at Davis Street, where they are 30 inches wide. The depth of the beam at the crown of the arch varies from

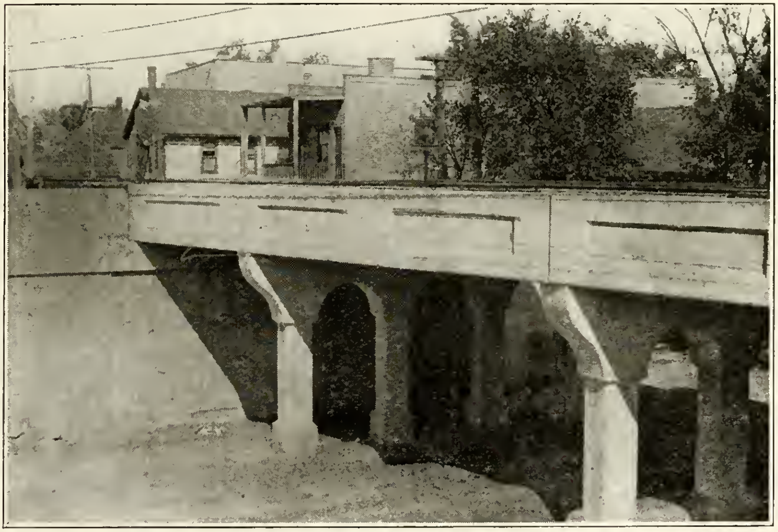

FIG. 6. VIEW OF LAKE STREET SUBWAY BRIDGE.

18 inches to 24 inches. The ends of the cantilevers are cut off perpendicular to the center line of the pier and the concrete slabs are allowed to project beyond the extreme corner, which gives a better appearance and a more satisfactory detail than would be obtained if the ends were made parallel and flush with the slab parapets, because the arrangement adopted eliminates the sharp corner and warped surface.

The column shafts from the springing line of the top arches to the top of the base or pedestal vary in height from 6 feet to 7 feet 3 inches. The top of the so-called base or pedes-

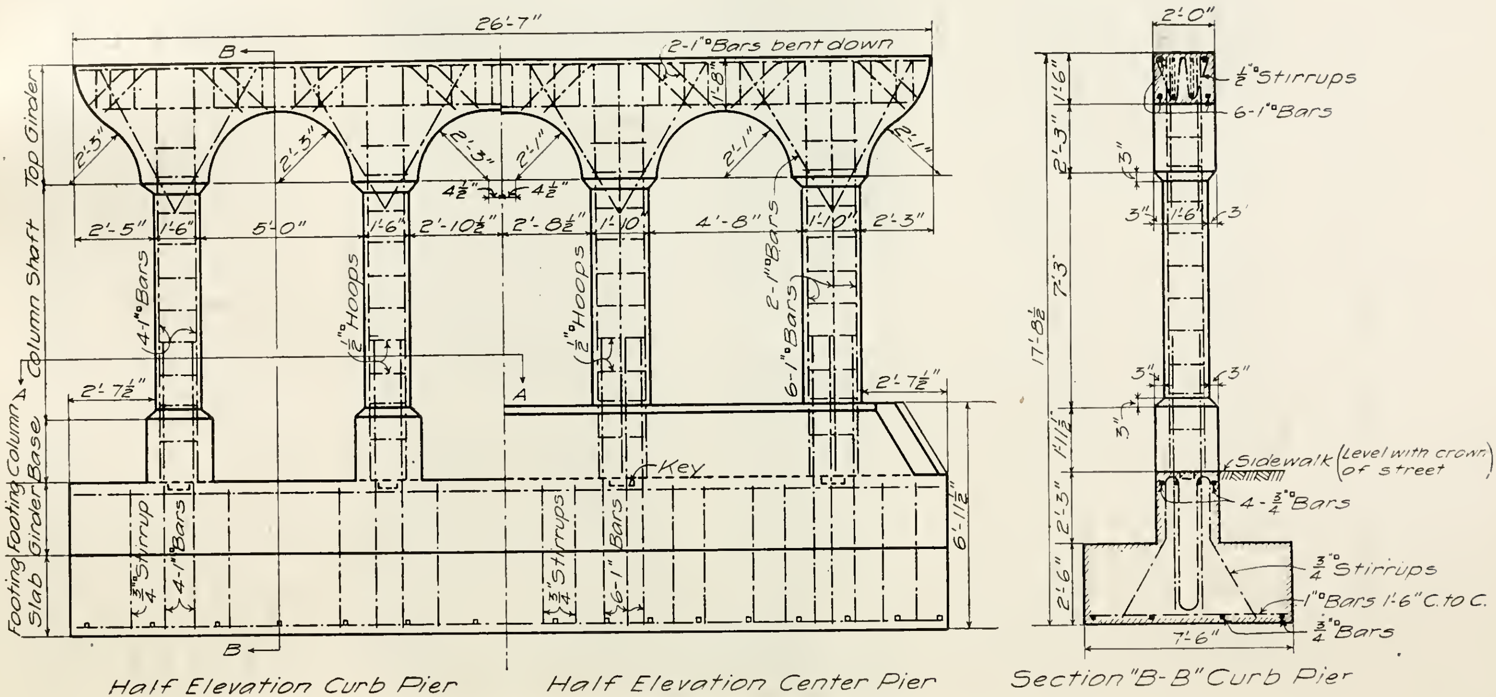

FIG. 7. DETAILS OF PIERS—CHICAGO AVENUE SUBWAY BRIDGE. . .

tal is 1 foot 11½ inches above the top of the curb or crown of the street. In the curb piers this pedestal has its horizontal dimensions six inches greater than the column shaft. In the case of the center piers, the pedestals are replaced by a continuous base or wheel guard running the full length of the pier and built with a starling at each end.

The columns are reinforced with about 1.5 per cent of steel, consisting of 1-inch vertical bars. This reinforcement is held in place by ties of ½-inch bars spaced 12 inches center to center vertically. The main column bars extend from the construction joint at the level of the crown of the roadway to the top of the top girder. Each one of these column bars is wired to a footing bar which extends from the bottom of the footings to a height of 4 feet 6 inches above the construction joint, thus furnishing continuous reinforcement from the bottom to the top of the piers to provide for any bending moment which is likely to occur. The concrete columns are 18 inches wide in a direction perpendicular to the center line of the roadway, except in the case of the center pier at Davis Street, where they are 24 inches wide. The dimensions of the curb columns are either 18 inches by 20 inches or 18 inches by 22 inches except at Davis Street, where they are 18 inches by 24 inches. The center pier columns are all 18 inches by 22 inches except at Davis Street, where they are 24 inches square.. The maximum stress on the column section is about 450 pounds per square inch, including impact.

A footing beam 27 inches deep distributes the load of the columns to the footing slab. The top of this beam is reinforced by ¾-inch bars extending the full length of the pier, and a number of ¾-inch stirrups tie it to the footing slab. The footing slab is 30 inches deep and varies in width according to the bearing area required to keep within the allowable unit pressure on the foundations. The slab is reinforced by transverse 1-inch bars. Four to five ¾-inch bars are placed longitudinally in the bottom of the footing to provide for possible inequalities in pressure brought about by variations in the foundation conditions, and to take any negative moment which might occur directly underneath the columns or in the side cantilevers.

The concrete for the piers, with the exception of the column shafts, is a 1:2½:5 mixture. The concrete for the columns is better than a 1:2:4 concrete. Square corrugated bars were used.

Design of Abutments:

The abutments are of the ordinary massive plain concrete construction of gravity section above the footing and have sufficient width of footing to keep the toe pressure within the allowable limit. Reinforced concrete abutments were not considered because it was expected that this work would be done during freezing weather. The abutments were figured for earth pressure (according to Rankine's theory) for a live load surcharge of 10,000 pounds per lineal foot of track spread over a width of 13 feet, and for the reaction of the slab spanning the sidewalk.

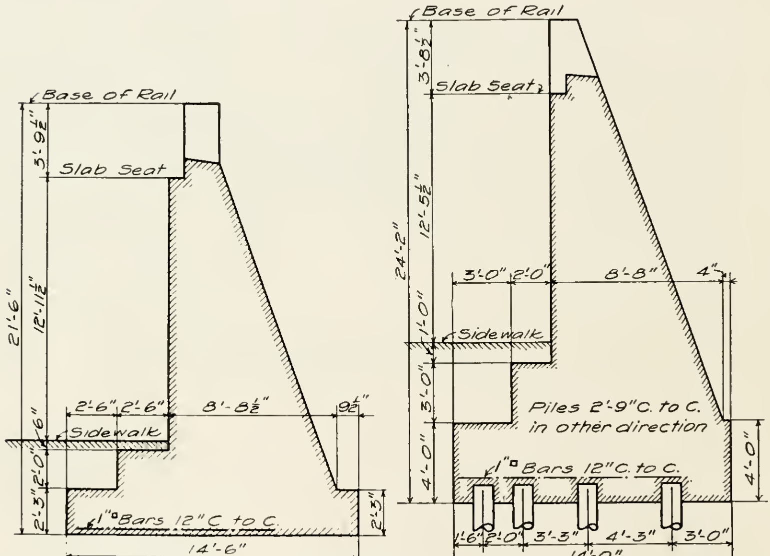

FIG. 8. SECTION OF ABUTMENT—CHICAGO AVENUE SUBWAY BRIDGE. FIG. 9. SECTION OF ABUTMENT—CHURCH STREET SUBWAY BRIDGE.

Fig. 8 is a cross section of the north abutment at the Chicago Avenue Subway. This abutment is 21 feet 6 inches high from base of rail to bottom of footing, and has a base of 14 feet 6 inches, making a ratio of base to the height of .67. The footing has a toe projection of 5 feet, reinforced by 1-inch bars. The step is added to keep the unit sheer low and make shear reinforcement unnecessary. Fig. 9 is a cross section of the north abutment at Church Street, which is on piles. The rows of piles are spaced in such a manner that the load on the extreme front row will never exceed the allowable bearing

value for the maximum lateral forces, and that the load on the rear row will not exceed the bearing for the minimum lateral forces. For average conditions the bearing on all piles is practically the same.

As shown by Figs. 8 and 9, a seat is provided near the top of the abutments for a width necessary to accomodate the sidewalk slabs. On either side of this seat the abutments are carried up level with the tops of the slab parapets and base of rail. The abutments which adjoin those of the Chicago & Northwestern Railroad subways have a slight batter on the front face and a coping under the bridge seats in order that the structures for the two railroads might be similar where they come into close proximity. The abutments for the other subways are made with vertical faces and without coping. The wing walls are carried out along the street line sufficiently far to prevent the slopes from encroaching on the sidewalks. The tops of the wing walls are sloped down 1½ to 1 to a height of 7 feet above the ground and are then carried level to the end in order to match up with the 7-foot fences. All abutments are designed with a view to providing for a future third track. The footings are built to the full width on the side upon which the future track will come and the wings are stepped down in such a way as to make the addition of future neatwork practicable.

Design of Slabs:

In all the subway bridges, except Davis Street, each track is carried over each span by a single reinforced concrete slab about 13 feet wide (12 feet 11¾ inches). The roadway openings at Davis Street are spanned by two slabs per track, as will be described later. As all of the subway bridges are on a skew varying from 2 minutes to 21 degrees 13 minutes, the slabs take the shape of parallelograms with their sides parallel to the direction of the track and their ends parallel to the center line of the street. The outside parapets of the track slabs are carried up to the level of the base of rail and are nine inches wide at the top. The faces of the slabs are panelled as shown in Figs. 4, 5 and 6. The inside parapets are made low and merely serve as curbs for the gutters, as shown in the detail, Fig. 10.

The slabs are designed for a live load equivalent to Cooper's E-50 loading plus impact, and for the dead load of track, ballast and concrete. It was assumed that the entire load would distribute over the full width of 13 feet. The presence of 15 to 28 inches of ballast and the transverse reinforcement as well as the large ratio of the thickness of the slabs to their

width, makes this a safe assumption. The longitudinal tension reinforcement consists of a double row of 1-inch bars laid in a direction parallel to the track and spaced as shown in the cross section, Fig. 10. The shear reinforcement consists of ½-inch "U" stirrups, assisted by the bent up ends of a number of the longitudinal bars, as shown in the detail. The transverse reinforcement consists of ½-inch bars spaced as shown. Inverted "U"-shaped handling stirrups are embedded at each end of the slab in a line parallel to the track and passing through the center of gravity of the slab. A rectangular depression around the tops of these stirrips gives room for the

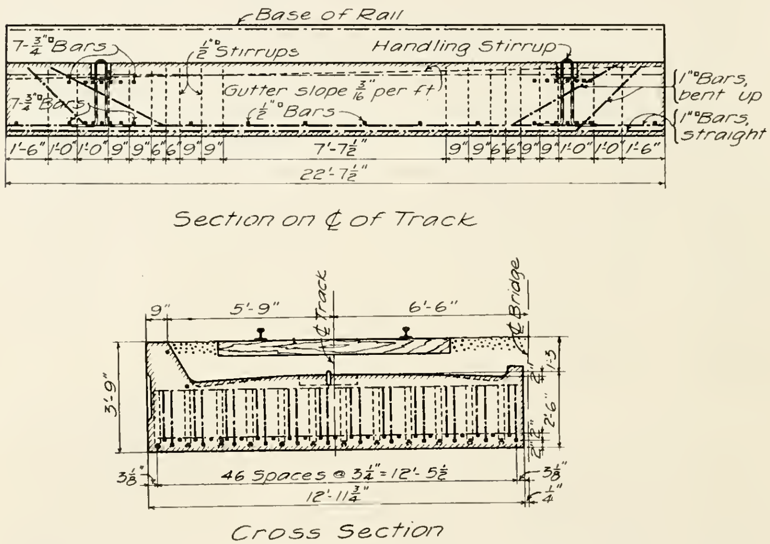

Fig. 10. Details of Roadway Slab—Chicago Avenue Subway Bridge.

lifting device. The ends of the stirrups are bent horizontally for a distance of 1 foot. Seven ¾-inch bars placed transversely in both the top and bottom of the slabs at each stirrup take care of cross bending stresses which occur during the handling of the slabs.

The roadway slabs, 13 feet wide, vary in thickness from 2 feet 5 inches to 3 feet 5 inches, making the thickness of the bridge floor from bottom of the slab to base of rail from 3 feet 8 inches to 4 feet 10 inches. The sidewalk slabs vary in thickness between 1 foot 6 inches and 1 foot 7 inches. The roadway slabs are given a crown of 2 inches under the center line of track, which provides for a gutter at each side with a min-

imum depth of 2 inches. These gutters are sloped from the center line of the bridge toward the abutments. The sidewalk slabs are sloped 3 inches between the curb piers and the abutments. This arrangement provides for draining the entire bridge floor in each direction from the center line of the street over the back of the abutments. The joints between the sidewalk and roadway slabs are to be sealed and waterproofed in such a manner that the water will pass over them. The half section, Fig. 4, shows the arrangement of slabs and direction of drainage.

The roadway slabs at Davis Street have an over-all length of 27 feet 6 inches, and it was found that a single slab 13 feet wide would be too heavy to handle; consequently two slabs were used, each 6 feet 6 inches wide. A difficulty was encountered in the design of these slabs due to the fact that the resultant of the live load does not pass through the longitudinal center line of the half slab. On account of this fact the intensity of the reaction near the inner edge was increased, making it necessary to provide for a greater moment at this edge than at the outer edge. This variation of moment was taken care of partly by varying the cross section, partly by varying the per cent of reinforcement, and partly by adding compressive reinforcement.

CONSTRUCTION OF SUBWAY BRIDGES.

The description of the method of constructing the subway bridges will naturally fall under two heads, the construction of the piers and abutments and the construction of the slabs. The slabs were built at a distance from the bridge site and placed in their final position after the piers and abutments were completed. The erection of these slabs was a problem in itself which will be described separately.

Construction of Piers and Abutments:

The building of the piers and abutments was difficult on account of the adverse local conditions, such as the narrow right of way (in some cases only 40 feet wide), the frequency of the electric trains on the double track line, and the presence of the overhead trolley wires. The trains were operated at 10-minute intervals for the greater part of the day and night, the only respite being gained between the hours of 2 a. m. and 5 a. m., when the interval was increased to 1 hour.

All excavation, driving of foundation piles, and placing of concrete footings were done, in so far as possible, before the construction of the falsework bridges and before the raising of the grade. The track was carried across the pits on wooden stringers. The foundation piles were of oak or tamarack, 24 to 30 feet in length. The standard track driver was employed

and it was necessary to operate the trains single track while the driver was in a position to work. The trolley wires were thrown aside as much as possible and the interfering span wires removed. Two drivers were used, and day and night shifts were kept busy. The night crew drove the piles farthest from the center line of track because in driving such piles the swing of the driver interfered with both tracks; consequently the time of night was chosen, in which the interval between trains was the greatest.

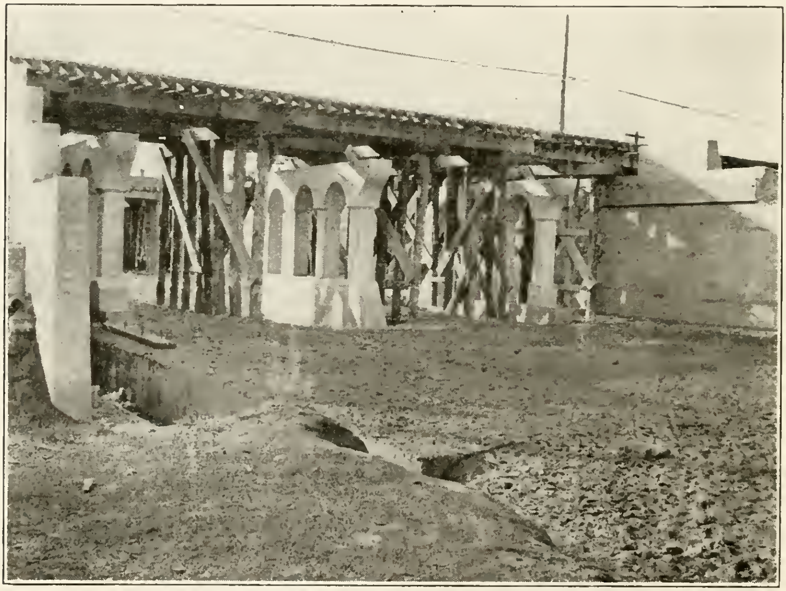

Fig. 11. View of Washington Street Subway Bridge Showing Piers and Falsework.

Pile trestles were put in over all crossings to carry traffic during the erection of the forms and the placing of the concrete for abutments and piers.

It was found impractical to use sectional forms for the piers to the extent planned, and only the forms for the column shafts and the centers for the arches were designed to be interchangeable. The sheeting for the column bases and the top girders was built in place. All sheeting was placed with joints horizontal and was composed of 2x8-inch lumber. Fig. 12 shows the details of the formwork for one column. The sections parallel to the side of the pier were made 3 feet wide

and braced by 3x6-inch vertical studs, and by horizontal girts running the full length of the pier. The sections for the column sides perpendicular to the face of the pier were made of the exact width of the column and fitted in between the side sections. The sheeting for these sections was nailed to 3x6-inch posts, which were offset at the bottom from shorter posts supported on the footing girder. The top posts were beveled at the top for the 3-inch offset to the top girder, and also afforded support for the arch centers. The arch centers were made up of solid semicircles of 2-inch lumber, and 1x2-inch lagging was used. The lagging was made just long enough to fit between the forms for the faces of the pier. The reverse curves at the ends of the piers were cut from 2x12-inch boards and were nailed to the inside of the side forms to support 1x2-inch lagging. Cleats were nailed across the tops of the pier forms to support the reinforcing bars in the top beam

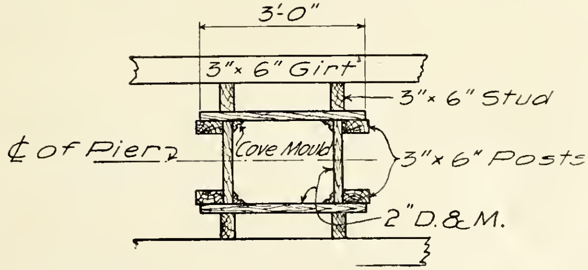

Fig. 12. Section of Column Form.

and to keep the forms from spreading. All steel was wired into place before the pier was poured. A loose board was left at the bottom of each column to make it possible to inspect and clean out the column form before placing concrete. To remove the forms it was only necessary to take off the side girts and the centering for the reverse curve cantilevers, after which the sections could be peeled from the face of the pier.

Forms for the abutments were of the Bridge and Building Department's standard type for such work, consisting of 2x8-inch form lumber supported by 3x6-inch posts spaced about 24-inch centers, which in turn were braced by double 3x6-inch girts. The forms were tied across by form-bolts and No. 10 wire.

Two alternate methods for providing the concreting plant were considered: (1) a mixer set up on the ground to handle material dumped at the site, and (2) a concreting train. The

first method proposed would make construction less dependent on train service than the second and would obstruct the track only during the unloading of material. The disadvantages of this scheme, however, were numerous; the equipment could not be used continuously, the concrete would have to be raised with a derrick or wheeled into position, and at many points the right of way was hardly wide enough to provide sufficient space for the accommodation of the plant and material. The method of concreting direct from trains was adopted. To permit the use of this scheme, both facing and trailing point-switches were put in at convenient intervals along the line. With this arrangement either track could be used over the various crossings and all trains were operated single track through the block while the mixer was in use. A pilot and switchmen were used to handle trains through the block on account of the fact that there was no dispatching system. There were three concreting trains operated and two No. 1 and one No. 2½ Smith mixers were used. The mixers were mounted on flat cars in such a position that the discharge just cleared the end of the car. The number of cars of material varied; the average was three cars stone, two cars sand, and one car cement, following the mixer in the order named. An old locomotive boiler was mounted and hauled in the rear of the train during the winter months to furnish steam for heating concreting materials.

Both chutes and wheel barrows were used in depositing the concrete. The use of chutes was found to be the least satisfactory for piers because it required that the train be spotted at each pier in turn, while the use of wheel barrows made it possible to concrete all of them at the same time, thus permitting the use of a larger crew and doing away with considerable switching and delay.

Construction of Slabs:

The slabs were moulded in the Howard Avenue yard at the south end of the track elevation, about an average distance of one mile from their place of erection. The ground on the site was first leveled and second-hand 12x12-inch or 8x16-inch sills were laid and driven to a uniform bearing with a 65-pound sheet pile pounder. A floor of 2x8-inch D. & M. planking was laid on the sills and the whole carefully leveled with an instrument. The slabs were cast to bring the direction of the span parallel to the joints in the floor. The forms for the face of the slab parapet were made up of 3x6-inch posts, 5 feet high and spaced 24-inch centers, sheeted with 2x8-inch D. & M. planking, which extended within 12 inches of the top of the

posts. The forms for the ends and backs were made of 3-inch x6-inchx4-foot 0-inch posts spaced 24-inch centers and sheeted with 1-inch S1S & 2E boards. The side forms were braced to 6x8-inch timbers spiked to the projecting end of the sills. The sides were made long enough for the longest slab, but were used for the shorter slabs as well, and each side and end was built as a complete section and moved from place to place on a push car. It was found possible to use each section about twelve times, after which the sheeting was renewed. The old lumber was used for backs of walls and abutments for sheet piling. Pairs of posts in the side forms were directly opposite, and a 2x8-inch or 3x6-inch plank was spiked to their sides above the sheeting. These timbers stiffened the entire form, affording support for the reinforcing bars, carried the forms for the back of the parapet, and sustained runways for the wheelbarrows. Fig. 13 shows these details. Blanks made up of 1x8-inch S1S & 2E lumber and 1x4-inch cleats were nailed to the inside of the parapet form to produce the recessed panels in the face of the finished slab.

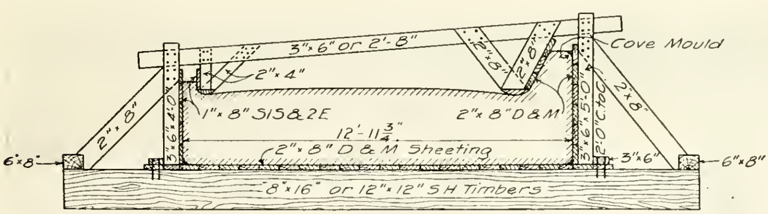

FIG. 13. DETAILS OF FORM WORK FOR SLABS.

The reinforcing bars and stirrups for the track slabs were cut to the proper length and bent to the required shapes at the yard. They were hauled to the forms on a push car and wired into place. The lower longitudinal bars were first laid on wooden blocks at the required distance from the top of the floor; cross bars were next placed and wired to the longitudinal bars to act as spacers, and finally "U" stirrups were hooked under the longitudinal bars at the bottom and supported by wire from the top cross pieces of the form. After all bars had been hung from the form in this manner, the small blocks were removed and the concrete was poured.

The concrete was machine-mixed, a No. 1 Smith mixer being used on the job. The mixer discharged into a hopper with a gate at the lower end, and each workman loaded his own barrow by lifting this gate. The mixer was spotted each day in the most convenient location relative to the slabs to be

concreted in that day's work. When the form had been filled to within about 4 inches of the top, the supporting wires were cut and pushed down into the concrete in order that the slab might be finished to the required surface.

Erection of Slabs:

The problems involved in the erection of the slabs were the transportation from the seasoning yard to the respective bridge sites, and the placing of them in their final position; all to be done in a way to cause the least possible interference with passenger traffic. The first idea was to transport the

Fig. 14. View of Slab Yard at Howard Avenue.

slabs on flat cars and place them with a derrick car or wrecking crane. The company had a number of 100-ton wrecking cranes and a number of 30- to 50-ton derrick cars available, and it was found that the sidewalk slabs could be handled readily in this way. The roadway slabs, however, averaged about 65 tons each, and needed special consideration. The use of a 100-ton wrecking crane was considered first. The slabs were to be handled by means of a triangular toggle frame attached to the handling rods which were imbedded in the concrete. The frame consists of a channel strut and two pairs of eye bars which extend from the ends of the strut to a pin

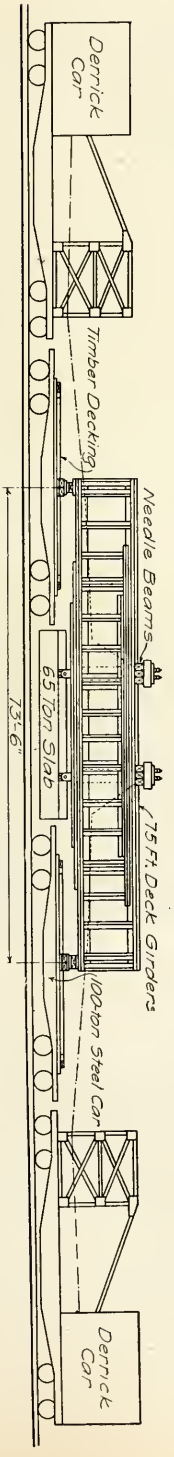

Fig. 15. Elevation of Slab Erecting Train.

over the middle of the slab. This device is used by the B. & B. Department in the erection of concrete trestle slabs. The use of the device requires a reach on the part of the crane equal to at least one-half of the length of the slab, and this reach could not be obtained in this case without a considerable out-haul and alteration in the body of the car. The next scheme involved the use of two derrick cars; one at each end of the slab. The cars were to be spotted at each side of the span and the slab was to be brought up on the second track and lifted from the flat car into place. This plan would interfere with traffic on both tracks to an undesirable extent and also would require an excessive side pick with the accompanying necessity for blocking outriggers and guying towers. A scheme for bringing the slab to the bridge site between derrick cars and on the same track was suggested as an alternative and found to be better in some respects, but far from satisfactory. At this juncture an erection device was suggested by Mr. C. F. Loweth which eliminated all the uncertainties accompanying derrick car erection, and it was used without any material modifications.

The general layout of the erecting device as used is shown in Fig. 15 and consists of a 75-foot plate girder span, taken from stock and temporarily available, mounted on two steel flat cars of 100-ton capacity. The cars are spaced to permit the slab to hang between them when attached to the girders, and are provided with a special timber deck of 8x16-inch timbers securely cross braced and bolted to the car body. Transverse to this decking are two 12x12-inch bolsters carrying a bearing plate upon which the bearing plate and timber bolster of the girders is placed. A king pin was passed through both plates and bolsters, and the plates were kept well greased to permit turning motion. The train pull was transmitted from the gird-

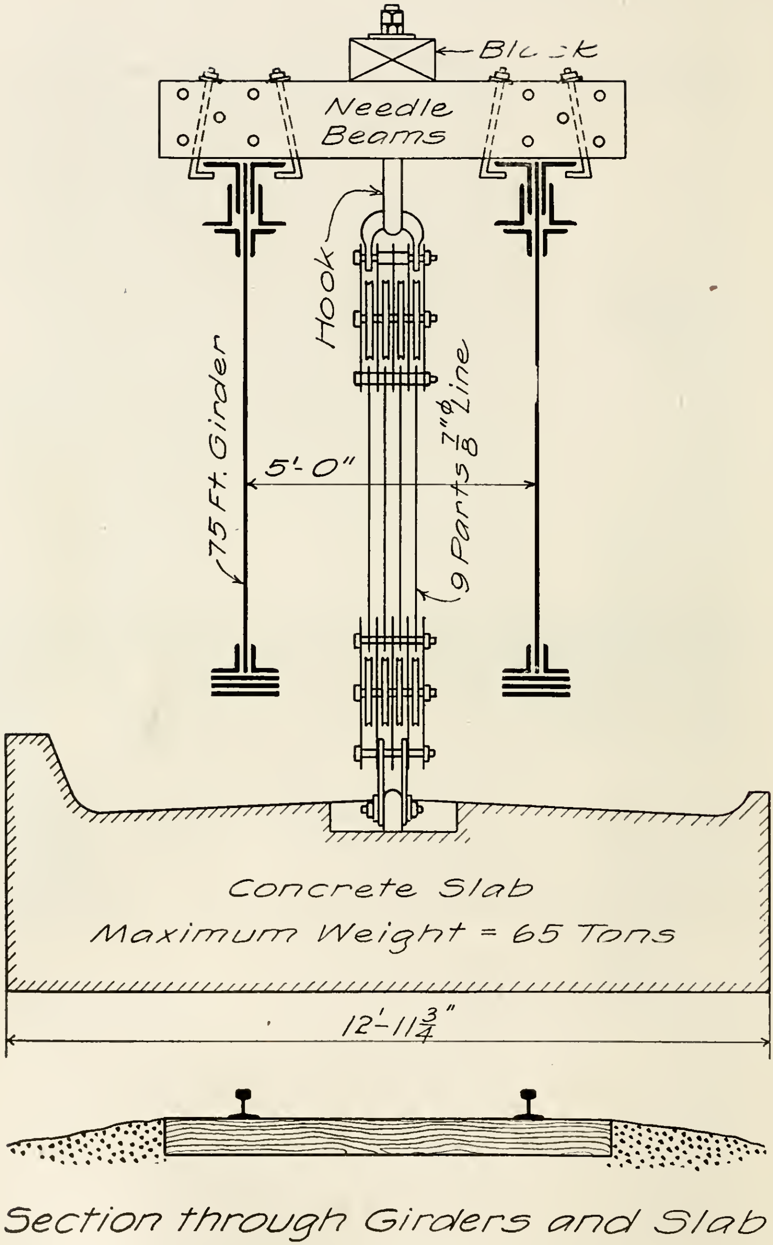

Fig. 16. Cross Section of Erecting Girders.

ers to the cars in each case by means of a special lower lateral system which provided a pin plate to receive the king pin. Fig. 16 is a cross section of the girders and shows the methods of supporting the slabs. Two pairs of 8x16-inch needle beams spaced 8 inches apart, and carrying a wooden block with a hook, spanned the girders. Each end of the concrete slab was suspended from a set of these beams (see Fig. 15) by tackle made up of two 4-sheave blocks and 9 parts 7/8-inch diameter wire line. The company had two derrick cars, completely equipped with engine, rigging and tackle, which could be spared from other work. These cars were cou-

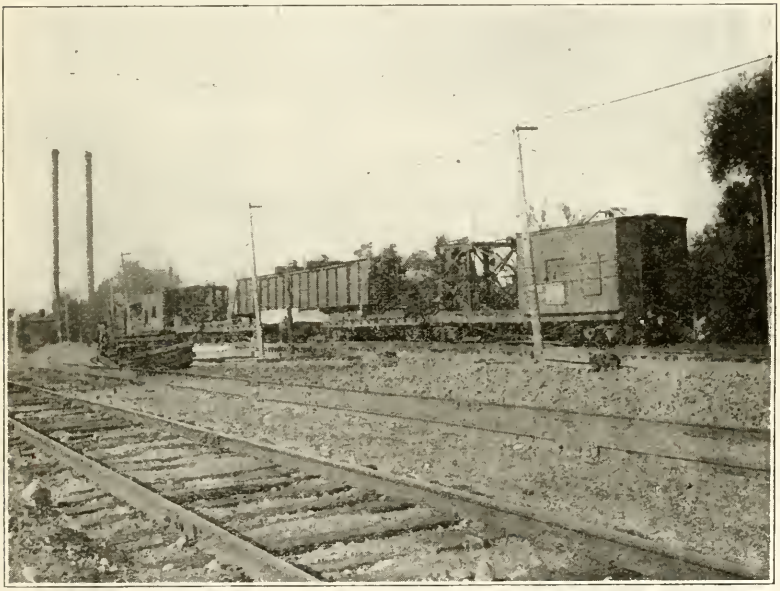

Fig. 17. View of Slab Erecting Train.

pled to the train, one at each end, and the lines supporting the two ends of the slab were controlled by the respective derrick car engineers. The procedure in placing the slab with this device was as follows: The slab was jacked up and placed on girder carriages mounted on rails. After the erecting train had been properly placed, the girder carriage track was extended across the main track, and the slabs were rolled underneath the girders, connected, lifted, and carried to the bridge site. The train was spotted in a position which would bring the slab directly above its final bearings, the track was removed, the falsework was torn out, and the bridge seats were

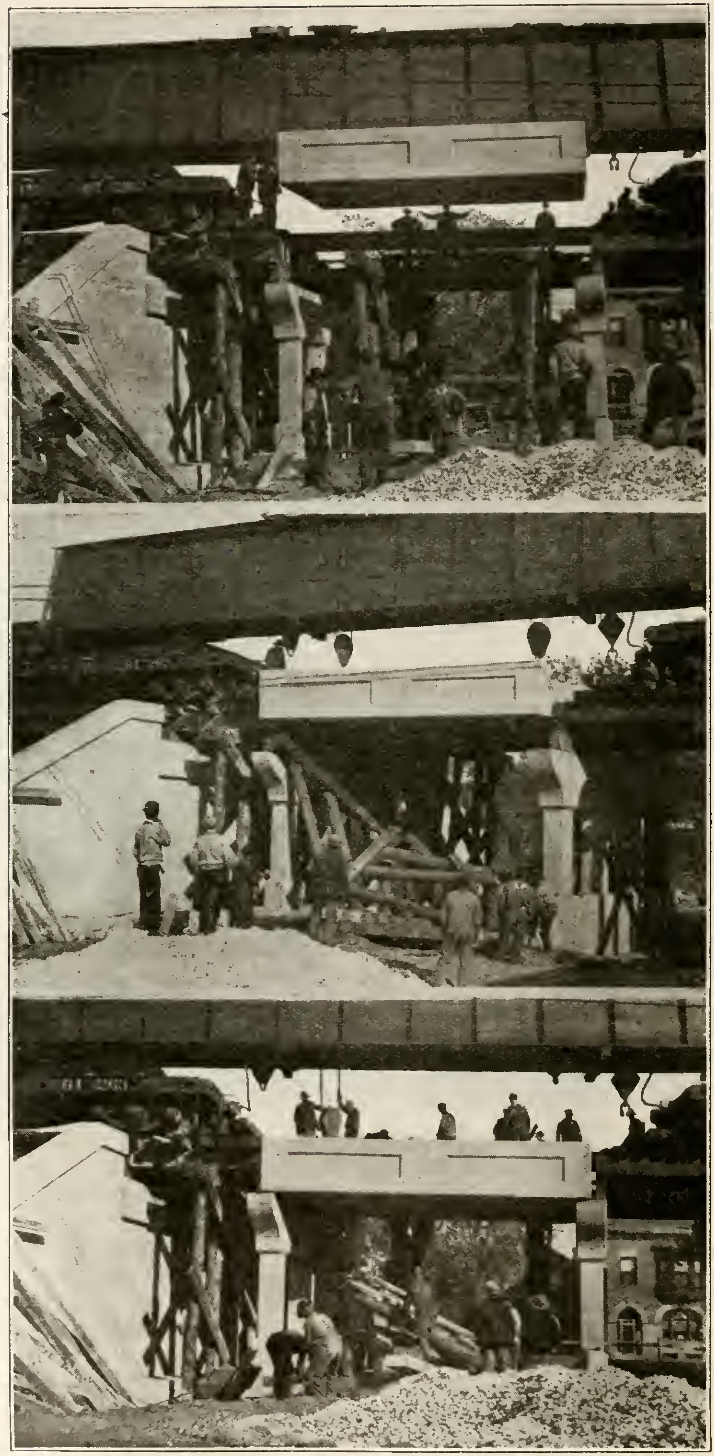

Fig. 18. Three Views Taken During Erection of a Roadway Slab.

prepared with a stiff cement mortar. When all was in readiness the slab was carefully lowered into place. By making the mortar of the right consistency and thickness, and by raising and lowering the slab a few times, it was found possible to bring the thickness of the bed to the required dimension and to line up the adjacent slabs in a very satisfactory manner. Fig. 18 shows three views taken during the erection of the northwest roadway slab at Washington Street.

RETAINING WALLS.

The right of way of the C. M. & St. P. Ry. through Evanston varies in width from about 40 feet to about 115 feet. The two tracks were elevated to an average height of about 17 feet above the natural ground surface, and, as mentioned before, provision was made throughout the work for the probable future addition of a third track. With these conditions existing, it would have been necessary to build a retaining wall along at least one side of the right of way for practically the full length of the track elevation, if it had not been for the fact that the right of way of the Chicago & Northwestern Railway adjoined that of the C. M. & St. P. Ry. for a large part of the distance. The two railway companies entered into an agreement in advance of the work, by the terms of which the space between the shoulders of their respective embankments was to be filled to the level of the tracks, and the cost of about 8,000 feet of full height retaining wall saved to each of the companies.

Design of Retaining Walls:

There is in all about 4,500 feet of retaining wall in the track elevation work, the walls varying in height, above the ground surface, from a mere curb of three or four feet to the full height of the embankment. With a few exceptions, the walls were of the ordinary plain concrete gravity section similar to the abutments. This type was considered an advisable one on account of conditions beyond the control of the designer. Rankine's theory of earth pressure was used in designing for the lateral forces. The effect of the live load surcharge was calculated on an assumption of vertical spread through the embankment. A maximum toe pressure of 1¾ tons per square foot was adhered to. As a general rule the walls were constructed in alternate sections; the sections are approximately 25 feet in length and the construction joints are marked with a "V" groove. The appearance of the walls is improved wherever possible by the addition of a coping and rectangular recessed panels. In cases where it is desired to provide for a future increase in height which might be made necessary by the shifting or addition of tracks, the design of the footings was modified and a heavy step is added to the back of the neat work in order that any future extension will

require a minimum of excavation and give the greatest stability to the final wall.

There were a number of inclined teamways required by the Chicago & Northwestern Railway adjoining the right of way of the C., M. & St. P. Railway, and at these points it was necessary to build retaining walls. These teamways are on a 5 per cent grade, making a total length of about 265 feet of wall necessary in each case. The height of the teamway varied from the street grade to the full height of the track elevation work. As the C., M. & St. P. Railway found it necessary to place its embankment before the fill for the teamway was made, a wall founded on the natural ground and capable of sustaining the embankment without front support, was required. With the teamway in place the difference of the elevation of the earth on the two sides, and therefore the overturning moment, for that part of the retaining wall at the upper end would be small, and the lower part of the wall would be buried and useless. On account of this fact the design shown by Figs. 19 and 20 was adopted as the most economical one under the circumstances. This design shows a full height solid gravity retaining wall to a point 90 feet from the summit of the teamway. The wall beyond this point consists of a curb coming 3 feet below the final surface of the teamway and supported on buttresses. The curb wall was reinforced as a beam to carry its weight between piers, and was made of a section sufficient to give it stability in itself. The buttresses or piers and their

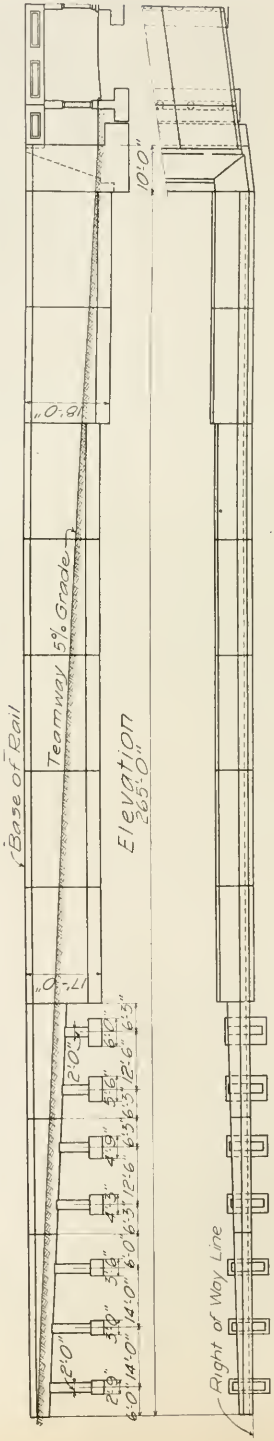

Fig. 19. Plan and Elevation of a Teamway Wall.

footings were proportioned to sustain the entire structure when under the action of the back fill before the teamway was in place without exceeding the allowable pressure on the foundations. The cross section, Fig. 20, taken between the two piers nearest the upper end of the teamway, shows the details of the curb wall and buttress, the relative elevations of the track and teamway, and the position of the slope line before the teamway was in place.

The ordinance required a concrete wall or fence 7 feet high for a distance of about 1560 feet along Chicago Avenue where the C. M. & St. P. Ry. was permitted to extend its right of way to the curb line. This wall is of variable section depending on the grade and the position of the nearest track. From Madison Street south there are two team tracks parallel

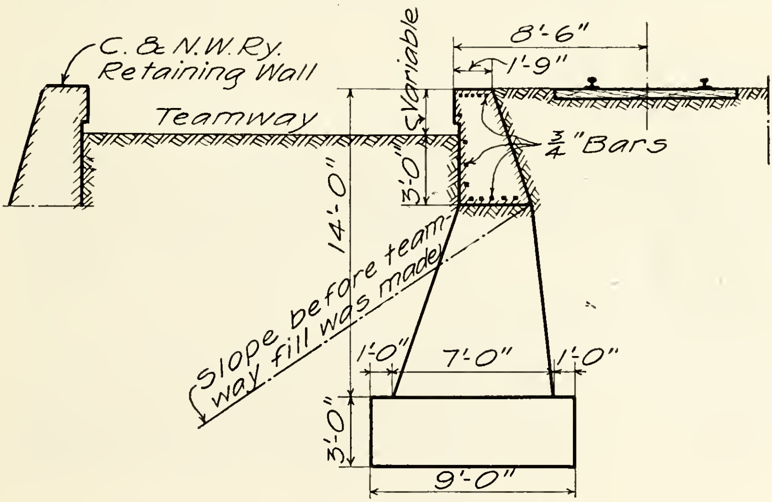

Fig. 20. Section of a Teamway Wall.

to Chicago Avenue, rising on a grade of 0.5 per cent. Fig. 21 is a cross section of the wall at this location showing the method of providing for the 7-foot height required by ordinance. The coping and panelling shown, serve to break the monotony of the long stretch of concrete surface in a rather satisfactory manner. The coping is continuous and the panels are 9 feet in length by 3 feet in height; the spacing between panels being 3 feet 6 inches. Fig. 22 is a view of this wall looking north toward Rinn street.

Construction of Retaining Walls:

The form work for retaining walls was of the department's standard type as described in connection with the construction of abutments. There were several cases, however, where the location of the tracks made it impossible to support

the forms by the usual outside braces, and in these cases the rather unusual expedient was adopted of tying the side forms to bolts embodied near the opposite edge of the concrete footings.

The concrete for retaining walls at some distance from the track was placed by means of a stiff legged derrick mounted on a flat car of the concreting train and carrying a concrete bucket designed by the department for this special purpose. Fig 23 is a detail of the bucket. It has a conical shape and is

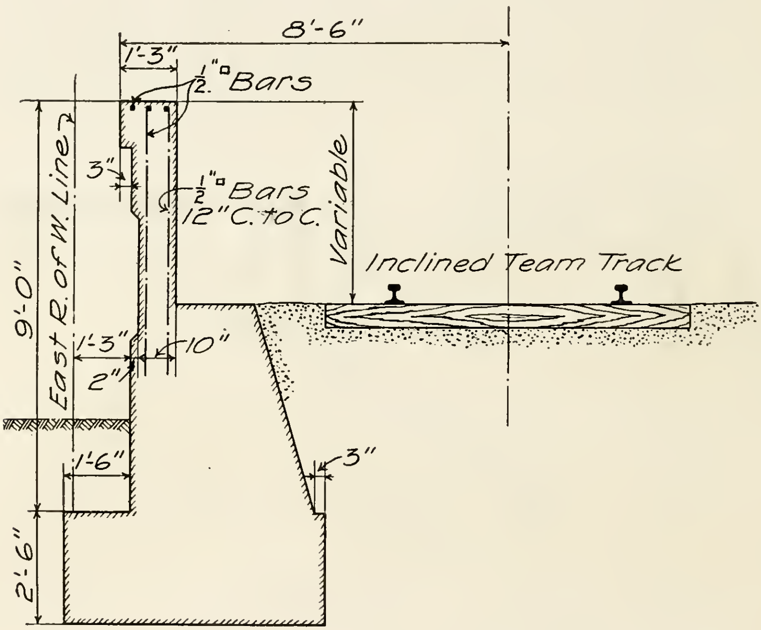

Fig. 21. Section of Wall along Chicago Avenue.

made up of sheet steel plates. A sliding discharge gate at the small end is controlled by a handle and a system of levers. The position of the levers and the gate while concrete is being discharged is shown dotted in the figure. This bucket proved especially convenient in discharging into narrow openings, and was very easily controlled.

STATIONS.

There are four passenger stations within the limits of the Evanston Track Elevation, known as the Calvary, Main Street, Dempster Street, and Davis Street Stations; they are about

one-half of a mile apart and situated as shown on the map, Fig. 1. The narrow right of way and the lack of space at the level of the elevated tracks made it necessary to place the station buildings at the street level.

General Arrangement:

Platforms from 225 to 240 feet long, sufficient to provide for six-car trains, were required. They were to be located on tangents, and the stairways leading to them placed as near as possible to the middle of the platform, that is, the platforms were to be middle-loading. The reasons for these two general

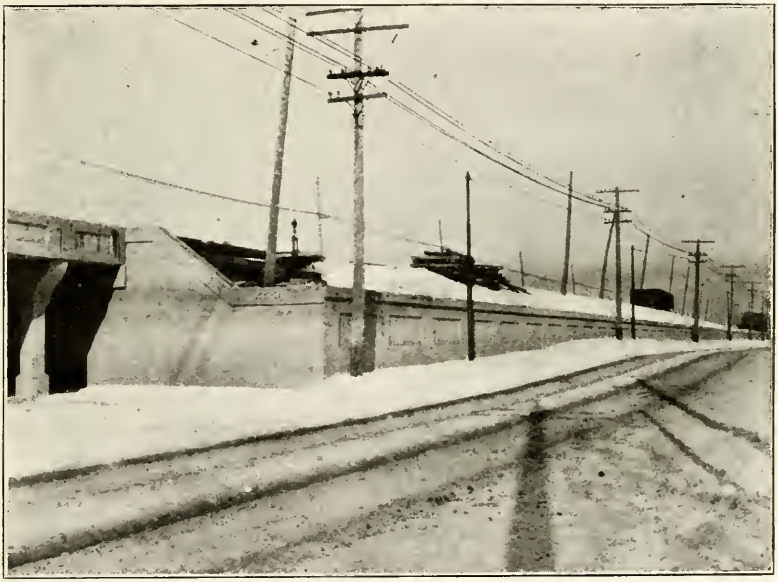

Fig. 22. View of Retaining Wall along Chicago Avenue.

requirements will be discussed in connection with the following description of the difficulties encountered and the solutions adopted.

For the location of the platforms with respect to the tracks, two alternative plans were considered; namely, platforms placed between the tracks, and platforms placed outside of the tracks. The advantage of the platforms placed between tracks, or island platforms, were, (1) smaller floor area required than for two independent platforms, (2) less difficulty in providing shelter, (3) no hand-railing required, and (4) shorter subways and fewer stairways needed. These plat-

forms presented several distinct disadvantages, however, in that they required the spreading of the tracks, four reverse curves, an additional width of embankment, and permitted passengers to change to cars running in an opposite direction without paying an additional fare for the return trip. Plat-

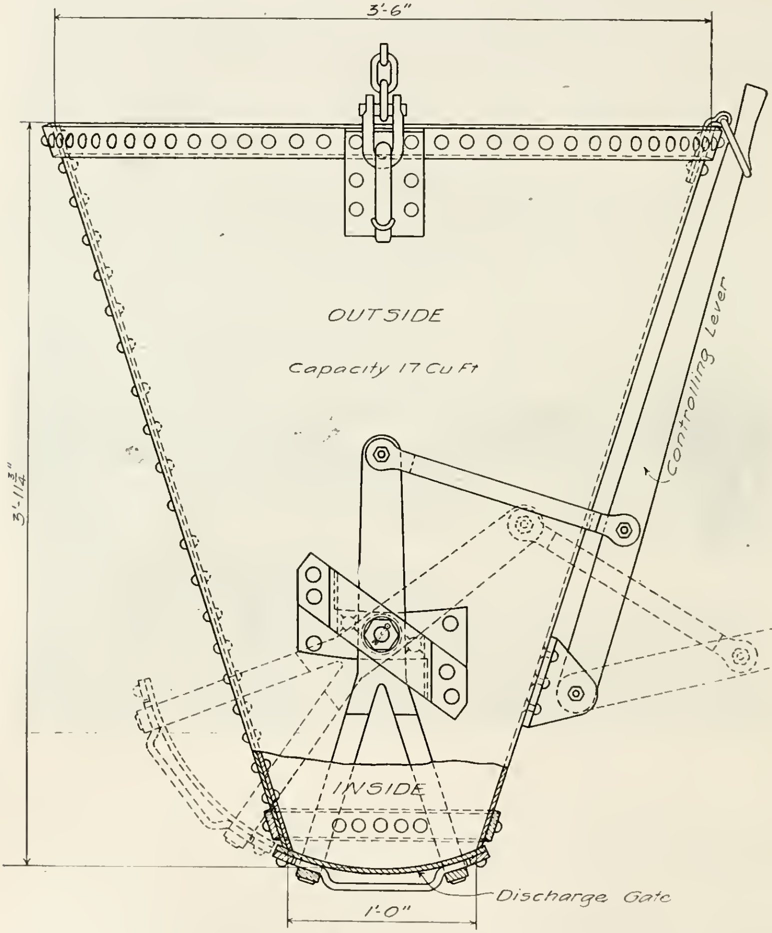

Fig. 23. Side Elevation of Concrete Bucket.

forms located outside of the tracks, that is, one platform for trains in each direction, had none of these disadvantages and, everything being considered, it was decided to adopt them in the final arrangement.

The location of the building proper with respect to the neighboring streets was the second important factor in the general layout, and was governed by the location of the platforms and by the requirements that the latter be middle-leading rather than end-leading. The first idea for three of the stations was to have the building directly underneath the tracks and facing the intersecting street. (Calvary station was to be located in the middle of a long block and was a special case.) Stairways were to lead from the station building to the middle of the two platforms. This would have made it necessary to extend the platforms over the intersecting street on the subway bridge. Such an arrangement might have been an advantage on account of its advertising possibilities, but it would have been objectionable from an aesthetic standpoint. Unfortunately there was a jog in the right of way at each of the streets at which the stations were to be located, which required heavy curves over Davis and Main Streets, and which would not permit both the station platforms and the future track over Dempster street. A middle loading platform, with the station building located as proposed was therefore obviously impossible at Dempster Street, and was ruled out at the other two points on account of the curvature of the tracks.

The reasons for restricting the location of the platforms to tangents will be seen from the following statement of conditions arising on curved track. On tangent track it has been the practice to locate the edge of the station platforms about three inches from the clearance line of the car. The floor of the platform being on the same level as the floor of the car, this would leave space of only three inches, for passengers to cross on entering or leaving. On a curved track, however, the middle of the car encroaches on the clearance line and makes it necessary to set back the convex platform beyond this line by an amount depending on the distance between centers of trucks and the degree of curvature encountered. The ends of the car move away from the platform edge and further increase the opening and, as a result, a considerable gap is left between the edge of the platform and threshold of the car. This gap is dangerous, and is likely to cause expensive accidents.

Since the platforms could not be brought over the subways, the only remaining scheme which would keep the station buildings on the intersecting street, was that which involved end-loading platforms. Platforms which are end-loading, are decidedly undesirable from an operating standpoint, because they tend to become congested at the end near the head of

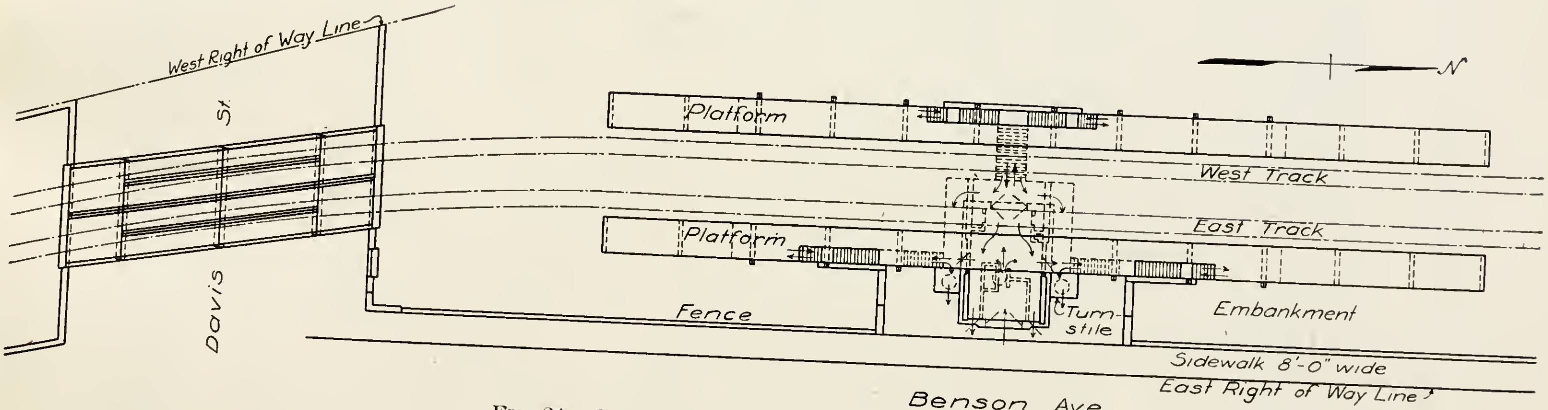

FIG. 24. GENERAL PLAN OF DAVIS STREET STATION.

the stairs through the inclination of crowds to hesitate about moving forward of their own accord. Passengers, crowded to one end of the platform when the train pulls in, will naturally all try to file through the nearest car doors and thus greatly increase the length of the stop. To obviate this difficulty, and to bring the stairways near the middle of the platforms, it was decided to locate the buildings between intersecting streets. Such an arrangement worked out very well on account of the location of north-and-south streets paralleling and adjoining the right of way.

The general features of the layout are shown in Fig. 24, which is a plan of the Davis Street Station. At this station the entrance faces Benson Avenue, which runs parallel to the tracks. The Dempster Street building faces the right of way of the North Shore Street Railway Co., and at the Main Street and Calvary stations the entrances are on Chicago Avenue. All of the station layouts are special; they depend on the width of the right of way and the location of the tracks. The general arrangement of the Davis Street station is typical, however, and will serve to illustrate the conditions. The building at this point is set about 4 feet from the inner edge of an 8-foot sidewalk, which is provided on the company's property between Davis and Church Streets to give access to the station. Passengers pass through the building, out of a side door on either end and up a front stairway to the east platform or through the rear doors and the subway to the back stairs and west platform. Incoming passengers leave the west platform through the subway and through the building, or through the subway and around the 6-foot passages to the exterior exit turnsiles. Passengers from the east platform find an exit through the turnstiles near the foot of the east stairs.

The Dempster Street station has a layout very similar to that at Davis Street, but the building is set further forward in this case and there are no side exit doors. All stairways are reached through the rear dood. Exit from all stairways may be made through either the interior exit passages or through the outside exit turnstiles.

At Main Street the station building is set even farther forward than at Dempster Street, but the scheme of circulation is no different. Fig. 26 is a section of the Main Street station taken along the center line of the building.

The Calvary station is a little different from the other stations because of the small ground area and head-room available, and because of modifications made on account of the funeral traffic to Calvary Cemetery, which has its entrance directly opposite the station door. The routes used in reaching and leaving the platforms are the same as described for

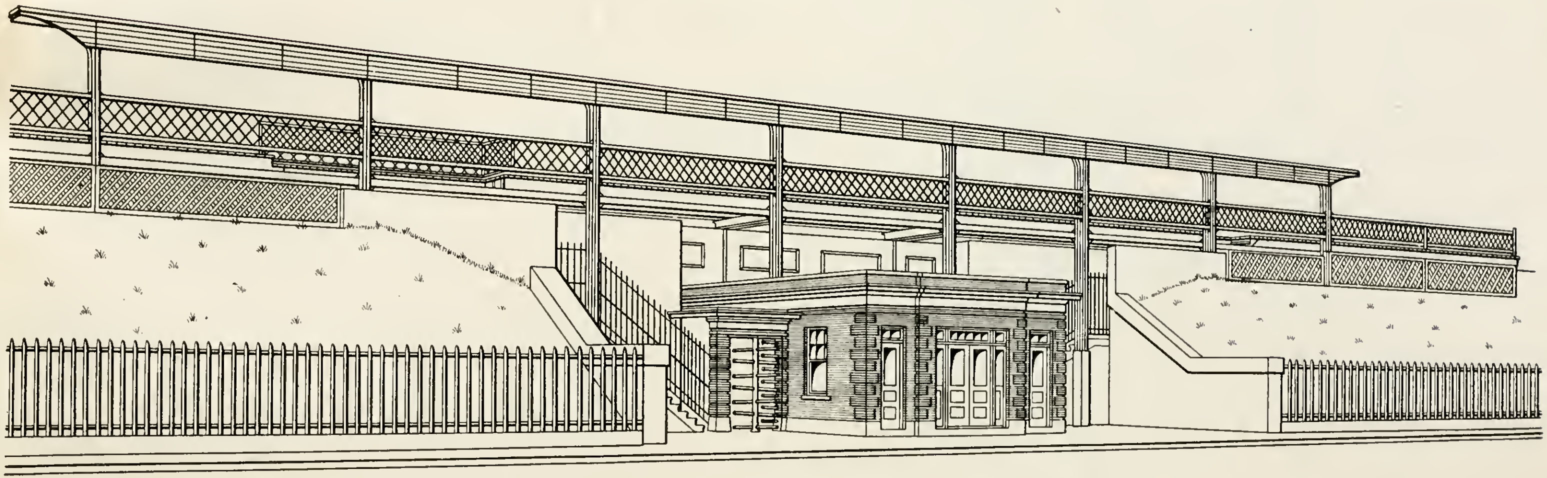

Fig. 25. Perspective of Davis Street Station Looking Northwest.

Davis Street with a few exceptions—namely: (1) exit through the station is not possible; (2) 6-foot wide gates next to the turnstiles are provided for caskets; and (3) 8-foot instead of 6-foot passages are allowed around the building.

The detailed design of the stations will be discussed under three heads—(1) reinforced concrete work; (2) the station buildings proper; and (3) the platforms, including the hand-railings and canopies.

Reinforced Concrete Work at Stations:

A considerable amount of rather interesting and complicated reinforced concrete work was required in the construction of the four stations. The necessity for this work was brought about by a number of conditions. First, the position of the buildings within the limits of the embankment required abutments, retaining walls and wing walls, and in some cases overhead bridges to carry the tracks clear of the roofs. Second, subways and stairways were needed to provide access to the platforms. Third, canopies were required to shelter the exterior passages as far as the outside turnstiles. Fourth, a probable future third track on the east side required a certain amount of present provision in order that such an additional track would not throw the station out of service or require extensive reconstruction.

At the Dempster Street and Main Street stations the parapets over the portal of the subways and two wing walls keep the embankment from encroaching on the space required for the station buildings and the side and rear passages. At the Davis Street and Calvary stations the buildings come under the line of present tracks and make overhead bridges necessary. These bridges consist of two abutments, two piers, and reinforced concrete deck slabs very similar in general arrangement to the subway bridges. The slabs between abutments and piers span the outside exit passages and the slabs between the two piers span the station building. On account of lack of space and in order to make a neater job the piers for the track slabs were incorporated in the sidewalls of the station buildings. These piers were made long enough to take care of the slabs which would be required for the third track. At Dempster Street, where no supports were required for the present tracks, columns and footings for future use were, nevertheless, constructed within the walls of the buildings. The reinforced concrete piers built within the station walls are very similar in design to the piers for the subway bridges, consisting of a footing slab, footing girder, two columns per track and a top girder; the curved brackets are omitted, however. The method of utilizing these piers in the construction

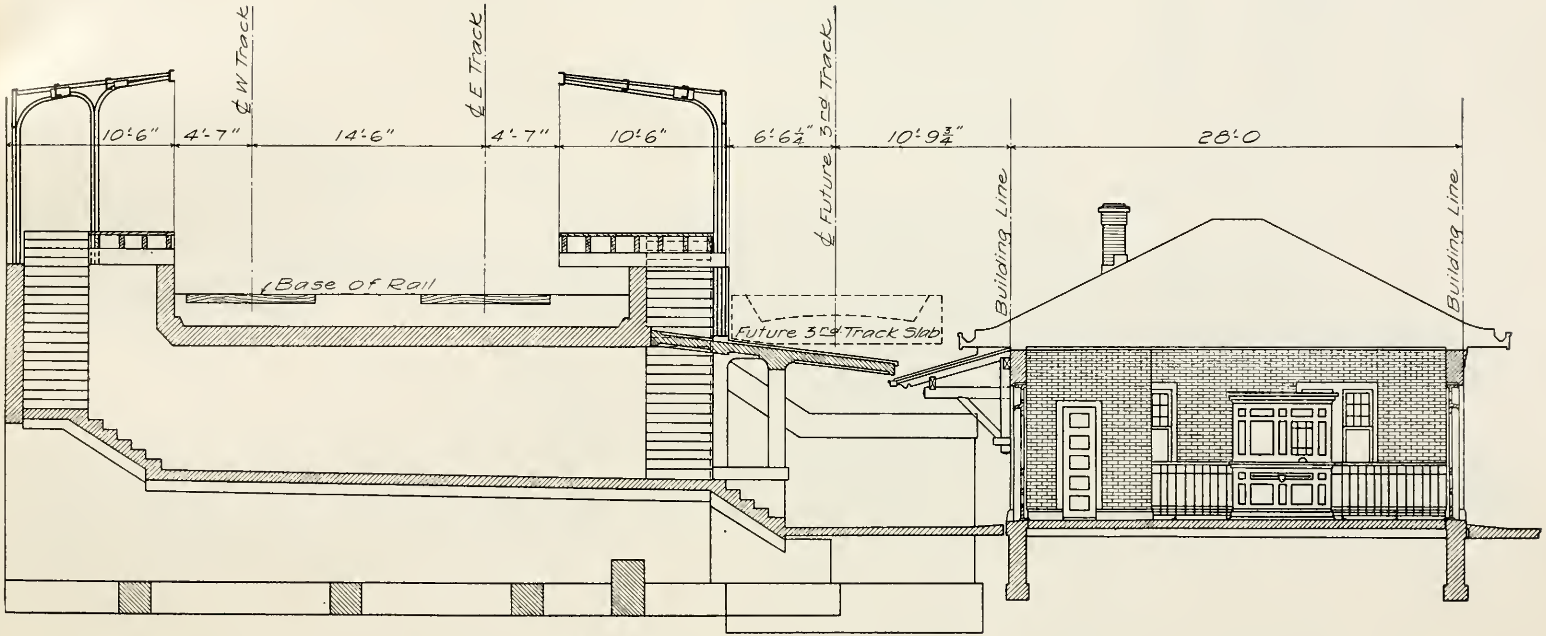

FIG. 26. SECTION OF MAIN STREET STATION ON CENTER LINE OF BUILDING.

of the buildings is taken up under the head, "Buildings."

The subways are of the same general type of construction as the standard reinforced concrete rectangular culverts built by the Department. They consist of two sidewalks designed as slabs to support the lateral pressure of earth, resting on footings of the required width necessary to provide sufficient bearing area, and spanned by reinforced concrete cover slabs. The footings are carried down to the same level as the foundations for the surrounding work. Struts between the footings take the horizontal reaction of the side walls. Four-inch projecting ledges cast on the inside of the subway walls afford a support for the pavement or floor slab.

The stairways are designed in various ways, depending on the conditions, but in all cases they consist of a reinforced stair slab spanning between two supporting walls. The stair slabs in the rear stairways rest on four-inch projecting ledges moulded along the lower edge of the supporting walls. Footings on the natural ground afford a bearing for the middle of these walls, and columns support each end. The tops of the walls are about 1 foot 9 inches above the base of rail. The stair slabs for the front stairways are also carried by two walls; the front wall, however, does not extend above the level of the stairs except near the top of the flight. The extreme ends of the supporting walls for the front stairways are not carried on columns; they are cantilevered instead, being tied back either to heavy mass abutments, to wing walls, or to the similar cantilever walls of the opposite stairway.

The subway floors and all the stair treads were cast after the supporting walls were in place, and they are finished with a granolithic surface one inch thick bonded to the main body of stair slab. The subway floors are crowned and sloped toward the entrance of the passage. Bell trap drains in the gutters catch the drainage from the sairways. The stairways have a rise of 7 inches and a tread of 12 inches; this tread includes a one-inch nosing. There is a ¾-inch fillet provided at the intersection of the tread and the face of the riser. The top landing is at about the level of the base of rail, and a wooden flight continues the stairway from this landing to the level of the platform.

Reinforced concrete slab canopies cover the exterior passageways in Dempster, Davis, and Calvary stations at points where protection is not afforded by the track slabs overhead. At Main Street station the conditions are a little different, and the canopy is supported on heavy wooden brackets bolted to the side walls of the building, the roof being the same as that of the main portion of the building.

The construction of piers to take care of the third track has already been mentioned. Wing walls running out as far as the toe of the present embankment are built at a considerable distance from the sides of the station in order to give as much light to the building as possible both under present conditions and after the construction of the third track slab. The footings for these wing walls are designed heavy enough to act as footings for the future abutment which will be built around the wings when the third track bridge is put in.

The footings for abutments, piers, and subways were kept separate, and proportioned to produce the same unit pressure on the foundation and thus prevent unequal settlement.

Station Buildings:

In planning the station buildings a number of requirements were kept in mind—namely: double entrance doors, ticket booth with turnstile, space for second booth which might be needed at some future date, an area in front of the stile, waiting room space beyond the stile, two toilet rooms, porter's closet, space for stove, rear exit doors (also side exit doors at Calvary and Davis Street), and two interior exit passages. All buildings have double entrance doors in front and double exit doors in the rear. Calvary and Davis Street stations have single exit doors on each side, opening on the front stairways. Interior exit passages are provided in all stations except Calvary and they have single doors at each end. The allowable width of Calvary Station is small and interior exit passages could not be provided. With the exception of the roofs and cornices, the details of construction of all station buildings are practically the same and can be described together.

The description will take up the foundations. exterior walls, roofs and cornices, interior arrangement and finish, plumbing and lighting in order.

The foundations at Main Street and Dempster Street stations are of concrete and of regular construction carried deep enough to avoid frost action. At Calvary and Davis Street, the foundations for the side walls are incorporated with the footings which carry the track slabs overhead. The front and rear walls are supported on concrete girders spanning between these side footings. A water-table carried up about 9 inches above the station floor level is moulded separately from the main body of the footings.

Thirteen-inch brick walls are built from the water-table to the bottom of the concrete cornice, or to the underside of the pitched roof, depending on the type of station. The exterior face brick for the main wall areas is light colored "Ori-

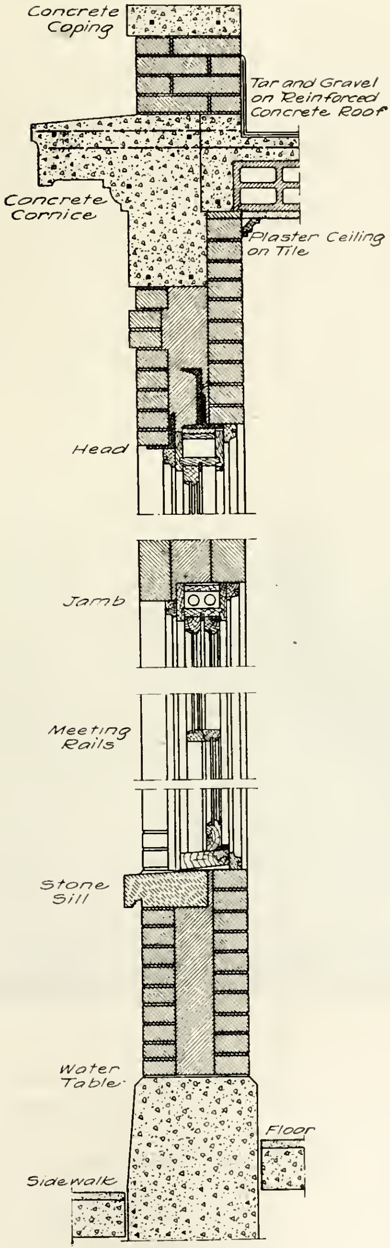

FIG. 27. TYPICAL SECTION OF A STATION BUILDING WALL.

ental,'' and a medium shade of ''Oriental'' is used for the projecting quoins at the corners and offsets. This difference in color is to give contrast. The bricks are laid up in dark red mortar; the joints are deeply recessed and ¼-inch in thickness. A white enameled brick was decided upon for the interior face after a number of kinds of light colored pressed brick had been considered. The great need for utilizing all the reflected light possible in these small buildings and the desirability of simplifying the maintenance, makes this brick the most economical in spite of its rather high first cost. The interior brick is laid up with ⅛-inch joints. The walls are filled with common brick and Portland cement grout, and wire bonds tie them together.

There are two types of roof used for the buildings. First,

Fig. 28. View of Calvary Station During Construction.

in the case of Davis Street and Calvary stations, and the rear portion of Dempster Street, the roof consists of a flat reinforced concrete slab supported by the concrete piers which are built into the station walls; the cornices in these stations are of concrete cast with the top girders of the piers. Second, in the case of Main Street station and the front part of the Dempster Street station, the roofs are of regular hip construction with a 3-foot projecting cornice. The stations with flat roofs have a concrete cornice of modified classical outline, above which is a brick parapet with a concrete coping. This

cornice is cast against the top girder of the piers which are incorporated in the side walls of the buildings at these stations. A reinforced concrete roof slab spans between the concrete piers. At the Davis Street station the span of the roof is 18 feet, and in order to reduce the dead weight, a concrete T-beam and tile construction was adopted. The roofs are waterproofed with a 5-ply tar and gravel roofing. The pitched roofs are of timber construction, weatherproofed with red French tile. A rather heavy cornice is provided, suggesting the "bungalow" style. The gutter and face board are painted a dark moss green; the panelled ceiling of the cornice is painted a somewhat lighter shade of green.

Since a maximum amount of natural light was desirable, as many windows as possible were placed in the side walls, due attention being given to exterior proportions. Transoms are provided above the doors, and a large panel in each door is glazed with plate glass. The requirements of the interior arrangement have been mentioned. The partitions for the toilet rooms and porter's closet are of white enameled brick laid up in single thickness, and set upon a concrete base to match the water-table. The interior walls of the toilet rooms are lined with white enameled tile. The ticket booths and all interior trim are of oak and have a dark greenish brown varnish finish. The glazing in the ticket booths is of ¼-inch clear wire glass. Flat-steel mesh screens are provided in a few of the panels of partitions and doors for the purpose of ventilation and transmission of heat. The interior passages are kept separate by ornamental iron hand-railings. The hand-railings have a "Bower-Barff" finish.

The floors are of concrete 6 inches thick with a 1-inch granolithic finish laid off in about 6-foot squares. The finish is colored and the surface is marked into squares (about 18 inches) to relieve the dead effect of the ordinary cement floor.

All plastering is on metal lath except at Davis Street station, where it is applied directly to the bottom of the tile and concrete roof slab.

Stoves are provided for heating. The flues lead to a brick chimney in the Main Street and Dempster Street buildings. In each of the other two buildings a cast iron flue is provided which passes through the ceiling horizontally along the roof and up the back of the platform canopies overhead.

All plumbing is open work and the fixtures are of "White Metal." The claim is made that tarnish can be readily removed from this metal without injury to the polished surface.

The stations, exterior passages, subways, and platforms are all well lighted. The various circuits are controlled by the ticket agent by means of a switch box placed inside of

the ticket booth. All wiring is done according to the Rules and Regulations of the National Electric Code. All lights are 16 c. p. incandescent lights connected in series, 10 lights to a circuit. With this arrangement of circuits, the failure of any one light does not affect the lights in the remaining circuits. An annunciator is placed in each station for the purpose of notifying waiting passengers of the approach of a train.

Station Platforms:

The station platforms are from 225 to 240 feet long and from 9 feet 6 inches to 10 feet 6 inches wide. The floors of the platforms are supported on the concrete stairway wall wherever possible and, beyond the stairways, are carried by pile bents. There are two oak piles per bent capped with 10x 12-inch timber, and the bents are spaced about 19 feet 9 inches center to center. Joists 3x12-inch, 20 feet long, spaced 18 inches on centers, and well bridged every 5 feet, carry the flooring, which consists of 2x4-inch S1S & 2E planking laid with ¼-inch open joints.

The platforms between the stair wells and about 25 feet beyond are covered by corrugated iron canopies supported on structural steel brackets. The corrugated sheeting is carried on channel purlins running between the brackets, and the whole roof is sloped downward to the back of the platform. The columns of the brackets are placed along the back of the platform to leave the floor unobstructed. They are made up of plates and angles attached at the bottom by means of a gusset plate to a pair of channels. The channels are firmly bolted to pile bents or concrete walls and the connections are figured for wind loads on either side of the canopy. Fig. 26, which is a cross section of the Main Street station, will show the arrangement in a general way.

Latticed struts brace the top and bottom of the brackets against longitudinal forces, and relieve any strain in this direction on the connections between purlins and brackets, and between brackets and their anchorages. The lower strut between the canopy brackets is designed to serve as a railing for the platform. The railings beyond the limits of the canopy are similar in design but much lighter. A pipe hand-rail is provided along the face of the stairway walls.

MISCELLANEOUS WORK.

Paving:

The grading and paving of the subways and their approaches were done by contract in accordance with the specifications, under the supervision of the Bridge & Building Department. The streets were paved with brick. The sub-grade was prepared by removing all rubbish, excavating and filling where necessary, and compacting by a roller. A 6-inch layer

of concrete mixed in the proportions of 1 part Portland cement, 3 parts sand and 7 parts broken limestone furnished the base. Upon this base was laid a paving of "Purington" paving brick on a 2-inch cushion of sand. The brick was brought to the face of concrete curbs, a combination concrete gutter not being considered desirable. The curbs were 6 inches wide by 36 inches deep, and were placed around the center piers as well as on both sides of the street. They were rounded to a 6-foot radius at street intersections and to a 3-foot radius at alleys. The sidewalks were made up of a 3½-inch layer of concrete with a ½-inch finishing coat of 1 to 1 mortar; the whole was laid on a 7-inch layer of sand. Expansion joints were provided at 40-foot intervals.

Filling:

The actual track raising was begun in the spring of 1909 and was carried on by the engineering department. To facilitate the handling of material a temporary yard was built at Howard Avenue, and the engines on the work usually tied up in this yard at night, thus eliminating delay on account of the late arrival of motive power. Side dump cars were used throughout the work and all material was unloaded by hand. About 300,000 cubic yards of material was used for the entire work. It consisted of sand and gravel hauled from the Fox Lake region.

The scheme of raising tracks was according to the usual methods. One track at a time was thrown out of service, cars were emptied, the material leveled, and the tracks were raised about 6 inches to 8 inches, ready for the next load to fill. When the difference in elevation of the two tracks became about two or three feet, the traffic was shifted and the low track raised.

Owing to the narrow right of way the problem of raising the tracks at some places was quite complicated, especially where space had to be left for walls which could not be completed before the elevation was begun. At such points a system of bulwarks was employed. The work over Main Street is typical. Retaining walls were required on both sides of the right of way north of Main Street and on the west side of Main Street. The tracks were first raised about 4 feet over the crossing and temporary bridges put in to keep the street open for traffic. North of the crossing the west track was raised as high as possible without interfering with the operation of the east track. Then the east track was thrown out of service in its turn and elevated, and a falsework bridge was put in across the street. Solid piles were driven on both sides of the track north of the bridge for a distance required to prevent the slopes of the embankment from blocking the

west track and northeast wall location. These slide piles were from 22 to 30 feet long and had from 10 to 18 feet penetration. They were driven about 7 feet center to center, and old ties were thrown in behind them to retain the fill. It was found that after a time they began to spread, and consequently were tied together by a number of strands of No. 10 wire running through the embankment just below the track.

Drainage:

The backs of abutments and retaining walls were not waterproofed. The fill was drained with 6-inch tile laid along the back of the walls, one drain served for retaining walls, but two lines were laid behind abutments, one near the bottom and one near the top. Tile pipe laid between the tracks drained the sub-grade. A combination manhole and catch-basin with about 3-foot interior diameter was placed behind each abutment. All drains were carried into the nearest catch-basin, and the catch-basin in turn discharged into the city sewers through a 9-inch pipe. The subways are drained by suitable inlets which were in all cases located at some distance from the street intersections in order that the depth of gutter and the step at the sidewalk crossings. might be as small as possible. The gutter grates were of the "Duplex" type. There was a catch-basin located at each inlet and one manhole in each subway.

The design and construction of the subway bridges, retaining walls, concrete work connected with the stations, station buildings and platforms, as well as the street paving and drainage for the entire track elevation work, were executed by the Bridge & Building Department of the Chicago, Milwaukee & St. Paul Railway, under the direction of Mr. Loweth, Engineer and Superintendent. The filling and track work were done by the Engineering Department of the Company. With the exception of a few minor contracts, all of the construction work was done by the Bridge & Building Department's forces. The construction and design, respectively, were, in a general way, in charge of L. D. Hadwen and J. H. Prior and were directly in charge of R. J. Middleton and of E. O. Greifenhagen, the writer of this article.

THE NATIONAL FIRE LOSS.

BY JOSEPH B. FINNEGAN, S. B.*

The Condition:

The annual fire waste in the United States has long been of such magnitude as to invite careful study and cause serious apprehension. The matter is one which is ordinarily dismissed as being of little importance to others than insurance men, inasmuch as the insurance companies are considered as the principal, if not the only, sufferers by fire. This attitude is possible only to those who have a wrong idea as to the nature of the fire insurance business and the functions of an insurance company. If a fire destroys a building, or a block of buildings, or even all the property in a town or city, the owners, provided they are insured, receive indemnity for the destruction of the value of their property, but this does not alter the fact that the value itself has disappeared absolutely and irrevocably; and that the community and the nation have suffered a loss for which the payment of certain sums of money by the insurance companies does not reimburse them. The insurance payments are made possible only because the companies have already collected premiums from practically all owners of property. Insurance is to be considered as an agency which divides and distributes the loss, and thus makes it endurable. The fact that the loss itself has been incurred remains, and the community as a whole is permanently impoverished More than that, the magnitude of the fire loss is such that it promises even to endanger the security offered to the individual by the fire insurance companies. Many companies were forced out of business by the San Francisco conflagration. The number of fire insurance companies that have withdrawn from business during the last fifty years greatly exceeds the number that are now in existence. Every great fire, and every year of exceptionally heavy loss has driven many companies to the wall. Even now, the owners of large values assembled in a single establishment are unable to secure insurance to the full value of their property without seeking it in Europe. The placing of these surplus lines has come to be an important factor in the business. It cannot be doubted that a great conflagration in the city of New York would result in putting out of business every fire insurance company in the United States, except those doing only a local business in other parts of the country. There is no reason why such a conflagration is not as probable in New York as it was in Chicago, or

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Baltimore, or Chelsea. The conditions that caused conflagrations in those cities exist also in New York. The means for checking and extinguishing fires are not enough better to give a guaranty of immunity against the greatest destruction of values in history.

The mention of heavy fire loss in the United States usually calls to mind the thought of the great conflagrations that have devastated Boston, Chicago, Baltimore, and San Francisco. Important as these fires have been, they tell but a part of the story of the tremendous loss. During the past ten years there have been nine other city conflagrations, each involving a loss of from two to eleven millions, and destroying property in cities in various parts of the country, including Bayonne, New Jersey; Hoboken, New Jersey; Jacksonville, Florida; Waterbury, Connecticut; Patterson, New Jersey; Cincinnati, Ohio; Rochester, New York; and Chelsea, Massachusetts. It is startling to consider that even these conflagrations account for only a relatively small part of the fire loss. In the year 1907 when there was no single great fire, the loss was about two hundred and fifteen millions; in 1908, nearly two hundred and eighteen millions. For the first three months of 1909, it amounted to about fifty-three millions, and it would appear that we may expect the annual loss to continue to exceed two hundred millions. These figures do not include the loss from the burning of forests, nor do they take into account the indirect cost of fire, such as the expense to the public of fire departments and water works. The National Conservation Commission, in a report transmitted to Congress by the President in January, 1909, states that the fire loss for 1907 including the value of property destroyed, maintenance of fire departments, amount of fire premiums in excess of loss payments, protective agencies, and additional cost of water supplies, reached a total of over four hundred and fifty-six millions, which amounts to thirteen times the interest on the total national debt, and to about fifty per cent of the value of new building construction in that year. It is rather a curious illustration of the indifference of the public in general to this matter, that a condition of affairs which amounts to the destruction of value equal to that of one building for every two buildings erected in a given year excites only a mild interest.

A comparison of the fire loss in the United States with that in European countries serves to emphasize the extravagance of our annual contribution to the flames. In American cities there are approximately forty fires each year for every ten thousand of population. In European cities there are about one-fifth the number, or eight for each ten thousand of

population. Berlin has a population somewhat greater than that of Chicago. Its annual fire loss seldom is greater than one hundred and fifty thousand dollars. The annual fire loss of Chicago is about five million dollars.

The average annual per capita loss in the United States is slightly more than three dollars; in Italy about twelve cents; in Germany forty-nine cents; and the combined average for Austria, Denmark, France, Germany, Italy, and Switzerland, is thirty-three cents, or about one-tenth of the loss in this country.

The destruction of material values is sufficiently impressive, and its economic effects are such as to justify alarm. There is, however, yet another side to the question, involving not only an economic, but also a humanitarian problem. Statistics assembled by the United States Geological Survey, show that during the year 1907, one thousand four hundred and forty-nine persons were killed in fires, and five thousand six hundred and fifty-four were injured. These figures are incomplete, and perhaps should be doubled to show the true number of victims of fires, inasmuch as the statistics were obtained largely from reports of fire department chiefs, and in the case of many large cities such reports do not include records of accidents or deaths. However, taking the statistics as given, they represent an annual death list many times that involved in the recent mine disaster at Cherry, Illinois, which evoked widespread sympathy, and active attempts to ascertain its causes and provide against its repetition. Public opinion was aroused to a marked degree by the mine disaster. It is necessary that the mind of the community should be awakened to a realization of the fact that every year the number of lives lost by fire is far greater than was the case at Cherry, and that, while it is important that the lives of miners be safeguarded, it is even more important that the lives of others imperilled by fires shall be saved,—more important because of the greater number involved.

The Causes:

An investigation of the causes which have led to the undesirable pre-eminence of the United States in the matter of fire waste would require a study of economic and social conditions, the full treatment of which is beyond the scope of the present article. Some phases of the subject, however, and those perhaps the more important ones, we may study to advantage. This country has been exceptional in the rapidity of its economic development. The accumulation of national wealth has gone on at a rate which is little short of marvelous. A large proportion of the annual increase in wealth is repre-

sented by combustible materials. The greater number of our buildings are subject to heavy damage or even total destruction by fire. One reason for this condition lies in the fact that wood has been the cheapest and most available structural material and has been used to a greater extent than other and more fire resistive substances. Another reason has been that the very fact of the rapid and comparatively easy accumulation of property has led to carelessness in its management and to an almost criminal disregard of ordinary precautions for its preservation. No one who has kept in touch with the history of the development of the country, especially in recent years, can avoid recognizing the fact that our marvelous resources, natural and artificial, are abused and wasted to a marked degree. Our forests have been devastated by individuals or corporations, who have taken an immediate profit without regard to the ultimate interests of the community. Our water powers have been exploited, to a considerable degree uneconomically. The care and study which are characteristic of great and successful manufacturing industries, the elaborate research and investigation which have made it possible to utilize practically every portion of the raw material and the product of a packing house or an oil refinery, have been conspicuously absent when it has been a question of economical administration of resources which belong to the nation as a whole. The lack of a proper national spirit of economy which is exemplified in the waste of national resources is fully as apparent in our attitude toward the destruction of property by fire. Men feel that they have little reason to fear direct personal loss by fire, since they expect to be reimbursed by the insurance companies. Buildings are erected with utter disregard of the fact that they are without safeguards against fire. City ordinances permit the putting up of structures of extreme height and excessive area, with unprotected openings in floors permitting rapid spread of fire throughout the building, and with unprotected exterior windows presenting no resistance to entrance of fires from an exposing building. Water supplies are insufficient in volume or in pressure. The careless methods followed by those responsible for the safety of our manufacturing and mercantile buildings, and even of our dwellings, is a prolific cause of fire. More than fifty per cent of the fires are from easily preventable causes. In discussing a recent fire, the Boston Herald makes the following editorial comment:

"There is a terrific loss of life and limb in this country from preventable causes. No other land shows anything like it, or anything approaching it. This is not because of the vastness of our population, but because of its carelessness. We are the most careless people on earth. We permit a looseness of conditions, a recklessness of method, or a method of recklessness, which would not be tolerated in Great Britain, or Germany, or France. This laxity runs on our railroads, pervades our coal mines, meanders in our mills, asserts itself in the slovenliness of our cities and our vacant lots, and is traced directly to our homes along the icy sidewalks to our front doors and the doors of our churches and public institutions. The average American cares no more about the conditions outside the walls of his home than he cares about the conditions on the most distant planet. We are indifferent and unashamed. The spasms of public horror are soon over and forgotten. They accomplish nothing."

The Remedies:

The fire loss can be reduced to a considerable degree by enactments of state legislatures and municipal councils. Such enactments may be of two classes; first, those by which the community itself provides means for extinguishing fires, and second, those by which property owners are required to maintain a proper standard of construction and protection in their buildings. In the first class would belong enactments carrying appropriations for fire departments and water supplies for fire fighting purposes. With regard to the former, it can be said without danger of misstatement, that fire departments in most American cities are already highly efficient. In the matter of water supplies, the conditions are less satisfactory. In many cities the mains are inadequate to provide a large volume of water at sufficiently high pressure to extinguish a large fire. In some cities, notably in New York and Philadelphia, high pressure water systems have been installed in addition to the ordinary systems which furnish water for industrial and domestic use. In the larger number of cities much remains to be done along this line. Besides efficient and well equipped fire departments and satisfactory water supply systems, ordinances and administrative methods leading to improvements in street pavements and drainage are of importance. A fire department can do nothing if its engines are bemired in muddy roads and thus prevented from reaching a fire. Another factor which has a bearing upon the reduction of the loss is the efficiency of the police force, not only because a good police department may reduce the number of incendiary fires

but also because the police are important auxiliaries of the firemen in the actual fighting of fires, since they prevent interference with the work of extinction.

Laws and ordinances having to do with the construction of buildings, and with the storage or handling of hazardous substances are usually assembled as a "building code." The codes in force in American cities vary widely, but in almost every case their requirements are less stringent than the corresponding regulations in force in European cities, and less stringent than they should be to secure the maximum degree of safety against destructive fires. Frame buildings should be prohibited in congested parts of a community. The height of a building should not be permitted to exceed a certain limit, determined by the height at which the fire department is able effectively to fight fire. In the same way, excessive areas should be prohibited, since they involve danger that a fire once started may spread rapidly and get beyond control. The application of this principle will involve the erection of interior division walls in buildings covering a large area. Vertical openings through floors for stairs or elevators should be properly inclosed in order to minimize the possibility of fire traveling upward from one floor to another. Exterior windows should be protected by shutters or wired glass as a safeguard against ignition of the protected building by an exposing fire. Satisfactory appliances for fighting fires originating within the building should be required. This may involve the installation of automatic sprinkler systems, interior standpipes, chemical extinguishers, pails of water or sand, one or more of the devices mentioned being required according to the characteristics of the particular building and its occupancy. Hazardous stocks, such as explosives or inflammable liquids should be handled with great precaution.

After all that is possible has been done in the passing of laws and ordinances, much yet remains to be accomplished. The really vital condition to be overcome is the general carelessness and almost universal lack of appreciation of the importance of the problem of fire waste, and the overcoming of this condition will depend not so much upon passing laws as upon the awakening of the people as a whole to a realization of their duties and responsibilities. Each man should be made to understand that upon him individually will rest the blame for a fire due to his carelessness or ignorance. He must feel that he has no right to erect a building that is likely to burn readily; that he has no right to use gasoline without proper precautions; that it is wrong for him to neglect to maintain

scrupulous cleanliness in his store or his factory; that he and his family cannot afford to use the deadly parlor match; that a fire resulting from overheating of the furnace flues in contact with a wooden partition in his basement is in the nature of a wrong to his neighbor and to the community. Every man should be an unofficial fire marshal to the extent of eliminating causes of fires so far as they are within his control. Physicians tell us that at no far distant time it will be considered disgraceful for a man to be ill. While the statement is of course an exaggeration it suggests much with regard to individual responsibility in the matter of health. With much less exaggeration it may be said that the true solution of the vital problem of our national fire waste will be found when in the eyes of the community that man is disgraced who tolerates such a condition of his property that it will burn and in burning impose a loss, directly or indirectly, upon his neighbors. It is probable that there will be fires in spite of all that we can do. When we reach the condition in which only these inevitable fires will occur, and when each man whose property burns is expected to show that it was through no fault of his, the national fire waste will no longer be what it now is, a menace to the prosperity and even the solvency of the business world.

THE GRAPHICAL REPRESENTATION OF CERTAIN FACTORS RELATING TO ELECTRIC DISTRIBUTING MAINS.

BY G. E. MARSH, B. S.*

The most profitable operation of an electric generating and distributing system depends upon the proper relation of many factors and efforts are constantly being made to express them in ways which will facilitate their study and assist in ascertaining their magnitudes under various conditions. In general, the factors can be separated into two divisions, those existing within the station and those exterior to it. The latter comprise the transmission lines, substations and distributing mains, etc.

The present article is concerned with the graphical representation of the various electrical quantities involved in the detailed consideration of direct current distributing or transmission lines. The subject may indeed be expressed to advantage as a formal problem, namely, a direct current main L feet long has E volts impressed on it at the generating station (or substation) and a current of I amperes, which is tapped off at intervals along the line. Determine the graphical construction of the voltage drop, current, power and loss curves of the line.

The solution is directly applicable to an outgoing distributing main, a trolley feeder, etc.

In the usual case, that in which the current is tapped off in unequal amounts and at irregular intervals, the "law of division of the current," as it may be called, would be difficult of exact expression and subsequent application. If, however, the current is reduced in fairly equal amounts and at approximately equal intervals, then the law of division is capable of being simply stated and the complete solution of the problem is easily attained.

If the main L feet long have a total resistance of R ohms and at equidistant points the current is tapped off in equal amounts, then the current in the line at a distance l feet from the supply is given by the expression

$$i = I\frac{L - l}{L} \tag{1}$$

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Obviously, the more numerous the points of subdivision of current the more correct will be the curves and the values derivable from them.

The current may also be expressed as a function of the resistance, r, of the line from the station to the point in question. Accordingly

$$i = I\frac{R - r}{R} \tag{2}$$

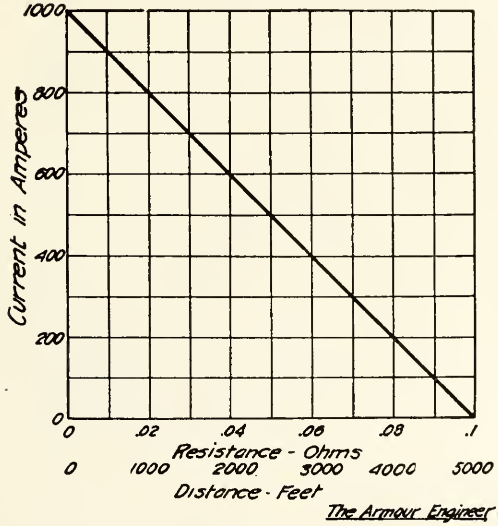

Fig. 1.

This last follows directly from the simple proportionality between l and r and which is the same as the relation between L and R, namely, the resistance of one foot of the line. Either variable may be used as the abscissa in the following consideration, but inasmuch as the latter is a purely electrical quantity, it can advisably be the one selected.

In Fig. 1, equation (2) has been plotted in terms of the variables i and r, and it thus gives the current curve of the main.

The fall in pressure or voltage up to any point is given by

$$d = \int_0^r i \, dr = \int_0^r I \left(1 - \frac{r}{R}\right) dr \tag{3}$$

$$= I\left(r - \frac{r^2}{2R}\right) \tag{4}$$

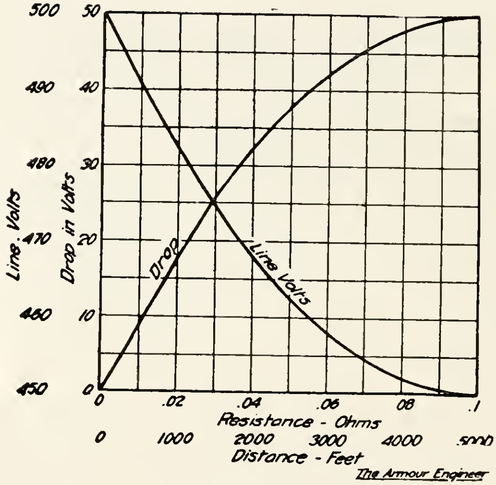

Fig. 2.

The last expression (4) is the equation of the drop curve expressed in terms of the two variables d (fall in pressure in volts) and r (resistance in ohms), and represents a parabola passing through the origin. Fig. 2 gives this curve.

The pressure at any point is given by (E—d) and may be plotted with the same abscissas as (4) and with ordinates obtained by subtracting the values d from the constant terminal pressure, E, as shown in Fig. 2.

The i^2r loss in the line is given by

$$w = \int_0^r i^2 \, dr \tag{5}$$

$$= \int_0^r I^2 \left(1 - \frac{r}{R}\right)^2 dr \qquad (6)$$

$$= I^2 \left(r - \frac{r^2}{R} + \frac{r^3}{3R^2}\right) \qquad (7)$$

If (7) is plotted in terms of the loss w and the resistance r, Fig. 3 is obtained.

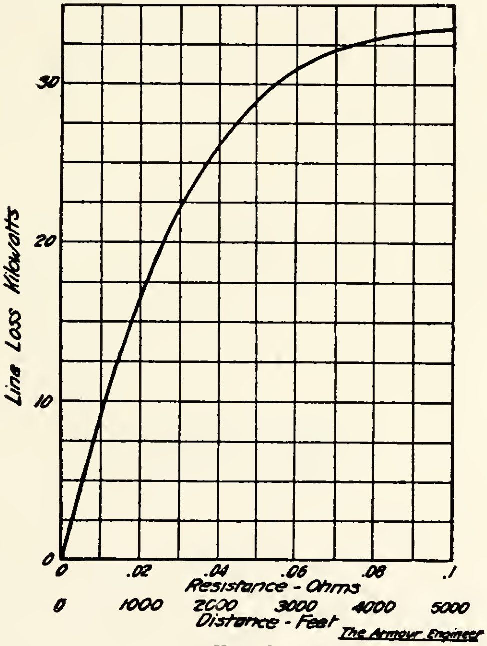

Fig. 3.

The power in the line at any point is

$$p = (E - d)i \qquad (8)$$

$$= \left[E - I\left(r - \frac{r^2}{2R}\right)\right] \left(1 - \frac{r}{R}\right) I \qquad (9)$$

$$= I\left[E\left(1 - \frac{r}{R}\right) - I\left(r - \frac{3r^2}{2R} + \frac{r^3}{2R^2}\right) \right] \qquad (10)$$

Equation (10) plotted in terms of p and r is shown in Fig. 4.

In the process of plotting equations (8) and (10), the work may be shortened by ignoring the terms involving r^3, as they are small in comparison to the others and hence their omission will not seriously affect the correctness of the curves.

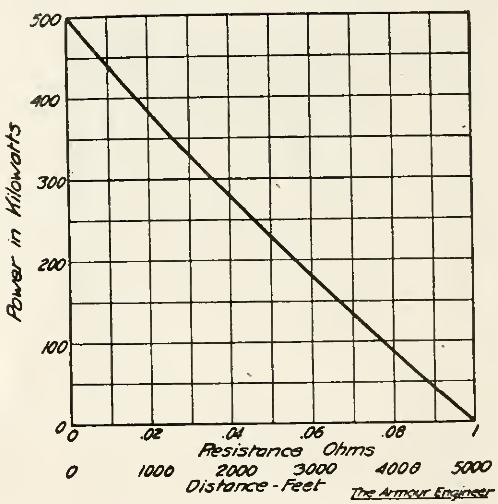

Fig. 4.

In the accompanying figures, the curves are based on the following data: I, impressed current, 1,000 amperes; E, impressed voltage, 500; R, total line resistance, 0.1 ohm; L, total length of line, 5,000 feet. This combination of data provides a terminal voltage of 450; that is, a line drop of 50 volts. These values were chosen merely as convenient magnitudes and are not actual working data. The application of the method to a graded main, one composed of sections of increasing resistance per foot of length, can be easily accomplished by a repetition of the process, and thus the curves obtained giving the values of the factors for each section and for the entire line.

THE WORK OF VALUATION OF AN ELECTRIC RAILWAY PROPERTY.

BY H. RALPH BADGER.*

The value of an electric railway property in a municipality today may be considered from a number of viewpoints. Passing beyond such of these as have to do with the purpose for which the valuation is taken, its fitness to fulfill the stated purpose and those which seek to accurately and equitably define the terms to be used in its expression, we shall consider solely the organization and actual work of making such a valuation.

The Commission:

Whether the valuation is to be made for the municipality in question or for the railway company, or for both jointly, the object sought being decided upon, the carrying out of the work is assigned to some kind of a commission. Generally this commission is one specially appointed for the purpose, and consists of from one to three men. It has four principal duties to perform: first, to lay down the premises upon which the valuation is to be made—unless these are stipulated in their appointment—in which case, the decision of any points not so covered; second, to outline the general method in accordance with which the work is to proceed; third, to develop an organization to carry out the detail, maintaining a general oversight of its work; fourth, to direct and approve expenditures necessitated by the work.

Organization:

The making of a valuation of an electric railway property necessitates a comprehensive organization, the general features of which are indicated in the accompanying scheme.

As seen from this diagram, the actual work of valuation is carried out under the direction of a supervising engineer, who is directly responsible to the valuation commission. Reporting to this chief of the engineering staff are a number of division engineers, one in immediate charge of each of the departments of the work. Under each of the division engineers are a number of assistants. A statistician, working in conjunction with the supervising engineer and the commission, superintends the compiling of data taken in the valuation, standardizing forms to insure consistent and logical presentation of the matter. Under him comes the stenographic and clerical force necessary to the work. A chief draftsman, under the direction of the

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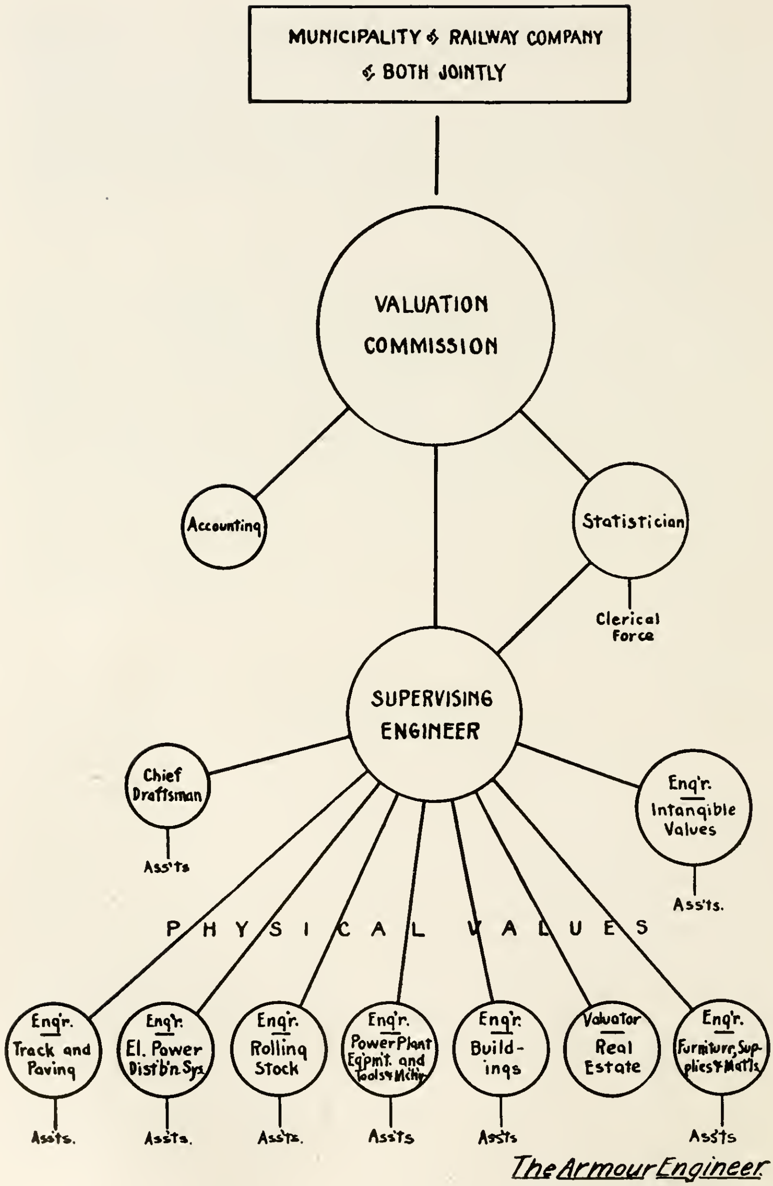
*Class 1907. Statistician with The Arnold Company in the Valuation of the South Chicago City Railway, the Calumet Electric Street Railway and the Southern Street Railway—1908.



Organization Diagram.

supervising engineer, and his assistants, reduce to final drawings all sketches made in the field. The accounting connected with the work is directly under the commission.

Valuation of Physical Properties:

This is effected by a careful examination and listing of all physical properties belonging to the company. A consideration must be made of the cost new (in place) of the various properties, the length and conditions of service, probable useful life remaining in them, and their scrap value.

The physical property valuation divides itself into two classes, field work and office work. The former consists of actual inspection and listing of properties wherever located, and the latter, the reducing to proper form of the data so taken. Experience shows that better results are obtained if each man who takes field data also reduces same to final form in the office, he being best able to interpret his own notes.

Outside of possible peculiar conditions present in particular cases, for purposes of valuation, a logical division of the physical properties of an electric railway would embrace the following departments: "Track," "Electrical Power Distribution System," "Rolling Stock," "Power Plant Equipment," "Tools and Machinery," "Buildings," "Real Estate," "Furniture, Supplies and Materials," and "Paving."

Track:

The work which comes under this department is divided into (a) line track, tangent and special; (b) track for car houses and yards, tangent and special; and (c) track on bridges, trestles, and culverts.

(a) Tangent Line Track. This includes all tangent track not in car houses and yards, or on bridges. It is divided into classes so as to cover all types of track coming under the valuation. These classes represent different kinds of equipment, the determining features being the section, weight, and length of rail used, the kind of joints between the rails, and the kind of ballast on which the track is laid. With such a classification first determined, the actual length of track coming under each class is measured in the field.

An estimate is made of the cost to reproduce one mile of each of these classes of track. In such estimates the cost of all materials, together with labor necessary to install these, is carefully considered. To the sum is added a percentage to cover the items of organization, engineering, and incidentals, which must have entered in the original production of the track.

From the unit price estimates thus obtained, and the total number of miles of each class of track, the total cost of reproducing the tangent line track is at once determined.

In depreciating these track values, the cost is divided into that of the rail and that of the substructure. The rail is depreciated both on account of joints and on account of wear on the head of the rail. Joints are depreciated by assuming a maximum useful life, and from this, an average annual percentage depreciation is obtained and charged against the cost new for the number of years they have been in use. The wear on the head of the rail is determined by measurement of the difference in height between this and the wagon tread. Knowing this quantity for the new rail as well, the amount of wear still remaining before becoming scrap, when the difference in height between the head and the wagon tread reaches a determined minimum value, is readily obtained. Readings are taken in the field of the existing difference in height, a vernier device being used for the purpose. Sufficient determinations are made for each section of rail to secure an average value. Depreciation for wear on the head of the rail is obtained by charging against the cost new of the rail an amount representing the percentage of the total wearing value of the rail when new that has worn away at the time of valuation. In depreciating the substructure a maximum useful life is assumed, and from this and the cost new, an average annual depreciation is obtained and charged for the number of years that the substructure has been in service. The kinds of material and construction used in the substructure are determined by field inspection along the entire line.

Line Track Special Work. This includes all track special work outside of car houses and yards, and that on bridges. Each piece of special work is inspected and measured in the field, a complete sketch of the same being made. Those pieces that are similar are grouped together and estimates of the cost new of one of each group are made. In these estimates, in addition to the cost of the special rail work, are contained the cost of substructure as well, and in addition to both of these, the overhead items of organization, engineering, and incidentals. Depreciation is applied to the track special work as a whole in the form of an average total depreciation, determined by inspection.

(b) Track in Car Houses and Yards. This is measured in detail for both the straight track and the special work. Considerations are made in accord with those above noted under the corresponding sections of line track.

(c) Track on Bridges, Trestles, and Culverts. The rail on bridges is inspected and listed. To its cost is added that of the fastenings necessary to hold it to the bridge, as well as the cost of any additional contruction necessitated by the

laying of the track on the bridge. Any trestle or culvert construction done by the company is inspected and an estimate of cost is made.

Electrical Power Distribution System:

The work coming under this department, in the case of an overhead trolley system, is divided into (a) trolley system, (b) feeder lines, and (c) signal and telephone lines.

(a) Trolley System. This covers all line material, such as poles, trolley wire, and cross-span construction, together with overhead special work at curves and crossings. The straight line overhead work is divided into sections for purposes of valuation, the limiting points of these sections being clearly defined. The overhead special work is considered by separate layouts, a sketch showing the material and its arrangement being made for each.

The materials coming under this division are listed by actual count in the field. Depreciation varies with different varieties of equipment and with different pieces of the same variety, and hence can only be applied as an average which is determined by an examination of the general condition of the whole equipment. A percentage, covering the organization, engineering, and incidental items, is added to the total of this equipment.

(b) Feeder Lines. These are inspected and listed. the sizes, lengths, and condition of each being noted. The only additional equipment included in this is that of the fastenings used to hold the feeders to the poles. Depreciation is applied by inspection. Allowance is made for overhead charges as in the previous sections.

(c) Signal and Telephone Lines. Under this the lengths and kinds of wire, the attachments, and the instruments are listed, depreciation being applied by inspection, and allowance made for the overhead charges.

Rolling Stock:

Under this division come all cars, whether standard passenger, special repair, sweeper, or sprinkler, etc., and car equipment. The cars are divided into groups according to type, style, make, and age. From each of these groups a typical car is chosen and of this a thorough inspection is made, careful specifications being prepared, giving details of the car equipment and construction.

The costs are figured for the separate items of car bodies, motor equipments, trucks, and miscellaneous equipment, which includes heaters, air brakes, fare registers, headlights, etc. Allowance is made as before for the overhead charges, although

a lower percentage is applied in this case. Depreciation is applied upon the age, condition, type, and suitability for service.

Power Plant Equipment:

The different parts of the power plants supplying energy to the line are carefully inspected and listed, together with an estimate of the cost. A percentage is added to the total cost estimate of the entire plant to cover organization, engineering, and incidentals. In determining the depreciation, the various kinds of equipment which go to make up the whole are considered separately. For each of these an annual depreciation is charged for the number of years such equipment has been in service.

Tools and Machinery:

Under this division all items representing fixed tools and machinery are brought together from the different shops and departments of the plants belonging to the company.

Buildings:

Each building belonging to the company is considered separately, the costs for the different items of material and construction being estimated for each, after a careful examination of same. The prices for the quantities entering into these are generally taken as those current at the time of the valuation, and to these are added the overhead charges. The depreciation applied to buildings is in general at the rate of one and one-half per cent per year of life. Particular conditions, however, may vary this.

Real Estate:

In valuating the real estate belonging to the company, it is more satisfactory to obtain the opinion of some one especially acquainted with this subject. Hence the services of an expert real estate valuator are generally sought, his figures being used.

Furniture, Supplies, and Materials:

The exact scope of this division may vary considerably with different companies. In general it covers furniture and fittings in the offices and waiting rooms, the various kinds of supplies, parts, etc., and miscellaneous materials on hand. A detailed inventory is taken of this and lists made giving description and quantities.

Paving:

It sometimes becomes a question as to whether the title of the paving placed along the tracks of the company lies with the company or the city. However, in valuating it, an inspection is made, covering the entire amount done and the kinds, quantities, and condition of each are listed.

Intangible Values:

The work of this division is obviously different from that of any that have gone before in that here the question is one of estimating probable future earnings of the company during the life of its franchises, and other rights which have not expired at the date of valuation. As these so-called "intangible values" are a question of future earnings, they are more or less problematic and open to a large number of influences.

However, in the work of placing a value on them, consideration must be given to the probable rates of growth of population along the lines in question, and a study made of the possible commercial or manufacturing developments in the territory served. Past traffic statements and operating expenses, as well as gross earnings of the company, must be available. With these considerations, together with a list of franchises granted to the company and the period of life remaining on each from the date of valuation to their expiration, an estimate is made of probable future earnings of the company. Other considerations such as good will, and in some cases patent rights, go to make up the total of the intangible values, the valuation of which in dollars and cents is at best difficult, and not at all exact in the sense that the "physical values" may be given.

The Report:

After all of the actual valuation work has been completed as far as the field inspection, listing, and office calculations are concerned, the compiling and presenting of the material obtained in the report is an important feature.

Starting this on the basis of an "exhibit" for each section of the work, logical division is made into as many exhibits as there are sections. These follow in the natural sequence suggested for the divisions of the work as previously listed. Under each exhibit, the first thing given is a summary of the different items coming under it. Following immediately is the detailed data whereby the totals shown in the summary are obtained.

The total of the amounts for each exhibit are placed in a general summary at the beginning of the report. To the sum of these totals is added a percentage to cover the general overhead charges of legal expense, carrying charges, brokerage, and contingencies.

Various illustrations, such as of the special track and overhead layouts, typical cars, etc., add much to the clearness and value of the completed report.

LABORATORY INSTRUCTION IN INDUSTRIAL CHEMISTRY.

A paper read before the Detroit meeting of the American Chemical Society.

BY HARRY McCORMACK, M. S.*

I realize that in selecting the subject of "Laboratory Instruction in Industrial Chemistry" as a topic for a paper, I have chosen a subject which is open to discussion from many points of view.

Laboratory instruction in "Industrial Chemistry" may be said as yet to be only in a formative period. Many and diverse plans in this subject have and are being tried by various teachers. I believe I am correct in stating that the different laboratory courses given in industrial chemistry will be as varied as the number of schools offering such a course.

There have been no text-books on the subject until the past year, when quite an excellent work was published. This text-book, however, follows rather the older ideas of presenting the subject and differs considerably from the idea of the course here presented. It contains excellent information and is a very marked advance on the previous condition of the subject.

The first courses offered as laboratory work in industrial chemistry consisted of analytical determinations as applied to the products of chemical industry. In fact, we might denote the course as being one of special quantitative analysis.

We are quite willing to admit the value of any and all instruction which the student may receive in quantitative analysis. Experiences of recent years, such as the co-operative analysis of the argillaceous lime-stone, the zinc ores, and the copper slag, as carried out under the direction of the sub-committees of this society, have shown quite conclusively that most of our men following the profession of analyst have yet something to learn about quantitative analysis.

Just what the fault has been in their training or experience may be difficult to decide. I believe, however, that later in this paper I will be able to point out how, by a properly conducted laboratory course in industrial chemistry, we will be able to correct many of these faults.

The next laboratory work offered as a course in industrial chemistry was what we might term a course in inorganic and organic preparations. We admit the excellence and value of such instruction, but we deny that it should be offered as work in industrial chemistry when it is carried out as it is in most cases. When these preparations are made on a suf-

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ficient scale, with proper instructions regarding the data to be taken, the course can properly be termed industrial chemistry. I would not call it so, however, when the instructions for the preparation do not include such items as analysis of the materials used in the preparation, their quantity and cost, the apparatus and labor involved in operation, the quantity and quality of the by-products obtained, and an estimate of the cost and value of each.

Some schools, having tried both methods of laboratory instruction to which reference has been made, reached the opinion that the ideal course was a combination of the two. The student, instead of examining the products of some factory engaged in chemical manufacture, is now instructed in the preparation and subsequent examination of his own products.

We realize, of course, that there are many limitations to the development of a course of this character. All lines of chemical industry do not lend themselves to the ready adaptation of their processes to such experiments as may be carried out on the "laboratory scale," and our ideas of what is meant by "laboratory scale" are continually growing. While we used to be satisfied with carrying on our laboratory filtrations using a funnel and filter paper, we must now have a filter-press; where we used to separate crystals from mother liquid by decantation, we must now use a centrifugal machine. The designing and building of such machines in small units has aided much in the development of a logical laboratory course in industrial chemistry.

It will perhaps be well at this time to outline the speaker's opinions of what should be covered in the laboratory course in industrial chemistry. First and foremost, there must be a logical and close connection between the lecture room work and the laboratory instruction in this subject. The laboratory work should so be planned as to bring out the following items: materials which are suitable for the construction of the various pieces of apparatus to be used in the manufacture of a certain substance; the methods which may be used in handling the materials, both raw and manufactured; the latter would include, of course, methods of transferring solids, liquids and gases, and the materials which might suitably be used in the construction of such conveyors. It will also include the study of the various methods of filtration, methods of concentration or evaporation and the various methods of distillation. We have in the past been making this instruction a large part of our lecture work and devoting very little time to it in the laboratory. We might as well attempt to teach the student how to estimate chlorine in sodi-

um chloride or iron in ferrous sulphate by only giving lectures on the subject. It is just as true in one case as in the other that practice in the actual manipulation is essential to the clear understanding of the process. The instruction in handling the apparatus finding an industrial use in the chemical processes should follow similar lines to those employed in giving instruction in analytical chemistry. In the one case, we treat of the chemical principles involved in a certain separation, the elements which may by their presence interfere with such separation, and how we may eliminate such interfering quantities and complete the determination correctly. In the other case we must treat of ideas of construction which may bring maximum efficiency, materials of construction which will not interfere with the satisfactory operation of our process, and with those conditions which may arise to impair the efficiency and success of our operations; and we must as far as possible treat of the methods by which such interference may be avoided.

The instruction as given in my own department commences with the study of machines and appliances which may be used in the chemical industries, the student being given some simple experiment which will require the use of a single piece of apparatus, and the experiment is designed primarily to present to the student the construction and operation of this simple piece of apparatus. He will probably also be expected to report on the efficiency of the machine from the standpoint of satisfactorily performing the indicated operation, and also, if it is a power-driven machine, he will be asked to report on its mechanical efficiency.

The preparation of industrial products involving the use of the more complicated pieces of apparatus is withheld until the student has a clear idea of the various appliances which he may be called upon to use.

The study of the appliances used is followed by the study of fuels. The laboratory part of this work will consist of applying the methods of analysis commonly used in testing fuels, and a critical study of the methods employed is also attempted. This is followed by a study of water from the sanitary and industrial standpoint. The student is here expected to make analyses of waters which are to be used for boiler purposes, to recommend a method of treatment which will improve the water in question, and, after discussing his recommendations with the instructor, the water is treated and then re-analyzed to show just what has been accomplished by the treatment. In the sanitary examination of a water the same general ideas are followed.

The student now commences his preparation of industrial products. An outline of the work required in a few of these experiments will be given to show what we are seeking to accomplish. From the inorganic products, I have selected (a) preparation of a phosphatic fertilizer, (b) preparation of portland cement, and (c) preparation of potash alum, as experiments which will indicate the variety and scope of the work.

(a) Preparation of Phosphatic Fertilizer:

A weighed quantity of the phosphate rock is taken and then ground to a predetermined fineness, the power factor being taken on all the grinding operations. A sample of the raw ground material is now taken and an analysis made to include the total percentage of phosphoric acid and the per cent of material reacting with sulphuric acid. From this the quantity of sulphuric acid necessary for conversion is calculated. The material is then treated with concentrated sulphuric acid and allowed to stand till the reaction is complete Analysis is then made for unused sulphuric acid and also the usual phosphatic fertilizer analysis. This experiment shows the students the steps necessary in the preparation of a fertilizer of this kind, familiarizes him with the methods of analysis employed, and shows him what may be expected in the finished product correctly prepared.

(b) Preparation of a Portland Cement:

The raw materials are crushed and ground. As this is the second experiment in which this operation is performed the students are not required to take the power factor on the operations of crushing and grinding.

The ground raw material is now sampled and an analysis made for the constituents which will influence the properties of the finished product. The calculation is then made of the proper admixture for the cement. The materials are then mixed and fused. During the fusion the temperature is noted with a pyrometer; the gas used is metered. When the fusion is complete, calculation is made of the calories required in the operation, and the cost of the gas used is noted.

The clinker after cooling is ground to the required fineness and the physical properties of the cement are tested. An analysis is also made of the finished product and this checked against the raw materials analysis.

(c) Preparation of Potash Alum:

Analysis of the clay is made to determine the quantity of aluminum present, and also to determine the presence of any impurities which may interfere with the purity of the finished product. A weighed quantity of the clay is taken, the

amount of sulphuric acid required is calculated and added, and the clay digested for some time. The calories of heat imparted during digestion are noted, and when the acid is neutralized, the digestion is stopped and the material leached with water, noting the quantity of water and the time required. Potassium acid sulphate in calculated quantity is added and after evaporation of excess water (calories necessary for such evaporation being noted) the potash alum is crystalized, and its quantity and purity determined. The second and even the third set of crystals may be obtained and treated in the same way, redissolved, recrystalized, and when of a sufficient purity, united with the first crop of crystals; the actual yield is then noted and this compared with the theoretical yield.

In the preparation of all the products the student is expected to take the data obtained in his experiment and use it in computing the cost of preparing the article for market. Each student is also asked to prepare plans and specifications for an establishment for some one of the processes. These plans are then brought before the class for criticism.

The work hitherto enumerated is given in the Junior year, which is the first year of the course in industrial chemistry. The directions for one Senior experiment are appended. This experiment is a diffusion test in the extraction of sugar from dried sugar-bearing material, either dried sugar beets or sugar cane.

This experiment has been preceded by one in which the student has dried the material he is now extracting, and this experiment is followed by several in which he works up the sugar juices here obtained, into granulated sugar and molasses. He also treats the by-products obtained from the beets or cane so as to put them in a marketable condition. He is directed to include the following in his report:

(1) Object of the experiment.
(2) Brief description of apparatus employed, this to include a rough sketch of the diffusion battery, showing the arrangement of the valves.
(3) The method employed in diffusing and the discussion of the theory connected with it.
(4) The tabulated results under headings,
(a) Data for curves in tabular form.

Brix.	Wt. of juice. lbs.	Av. Brix. o	Total sugar juice.	Vol. of juice cu. ft.	Extraction. %

(b) Approximate composition of dried cane by analysis.

(5) Discussion of results.

(a) Meaning of curves.

(b) Comparisons of process with present method.

Let us now analyze this experiment to see what is expected to be brought out in it and to note the determinations required of the student in performing it.

First, he gets an idea of how to look over a system of pipes and valves so as to control the flow of the liquid in any direction he may desire. On the surface this appears to be a very easy matter, but we find that it usually takes the student some time to solve this properly. It may seem to be a small matter, yet those of my auditors who are connected with the chemical industries may have experiences similar to one related to me by the superintendent of an establishment, where a young foreman, by turning one valve the wrong way allowed several hundred dollars worth of a product to flow into the sewer during one shift instead of into its proper container.

Second, the discussion of the method of diffusion and the theory connected with it has led to some interesting observations upon the part of the students. For example, one student notes the fact that in the method of diffusing the ordinary saccharine products, where the sugar is removed primarily by osmosis, as the percentage of sugar remaining in the product decreases, the per cent of non-sugars going into solution continually increases, thus lowering the purity of the juices. In this experiment it was noted that the purity of the juices remains about constant and the student advances the explanation that it must be caused by the rupturing of the cells of the sugar-bearing material during drying, and that he has consequently, instead of performing an experiment in osmosis, been simply lixivating the sugar from the other materials. Therefore, the per cent of sugar and non-sugar going into solution will bear a constant ratio.

We would consider the time remarkably well spent in such an experiment if we could only have one such a keen observation from each student on each experiment performed. Many other observations have been made by the students performing such experiments, not all of them correct, but all showing that we are accomplishing the prime object of our course, which is to get the student to observe and think for himself.

Consider, too, for a moment, the large quantity of analytical work which the student will have to do in performing such an experiment: he has to become familiar with the technical methods of estimating sugar in all its forms. This includes, of course, manipulation of the polariscope and the use

of the Brix spindles and their correction tables; methods for the estimation of cellulose, and in fact most of the determinations which would be included under the analysis of the food stuffs.

I will not weary you by giving in detail any of the other experiments we ask the student to perform, but wish to take a little of your time to tell of what we think we have accomplished by treating our subject in this way.

We believe we have been able to give our students an insight into the apparatus and processes in industrial chemistry, such as they could obtain by no other method. We are making him, to a considerable extent, independent of his instructor and dependent upon himself for observations and conclusions. We are succeeding in having him perform a very large quantity of analytical work and at the same time retaining his interest in this work, so that it is not burdensome.

Before inaugurating this course we gave courses in fuel analysis, water analysis, food analysis, etc. The student would examine a few fuels, probably one or two waters, and a few of the different materials used as food stuffs. He thought he was working very hard, accomplished little, and was not particularly interested in his work, because he did not see its direct utility. By making these analytical determinations an integral part of the course, in other words, convincing him that he needs this work in his business, we are able to give him very much more of the analytical work and at the same time to also give him work which we believe is of as great, if not a greater value.

This emphasizes the point mentioned previously in this paper, that the student needs to do a large amount of analytical work to properly prepare him for his duties after graduation.

I trust I have shown how this may be accomplished without making such analytical work a burden. In my opinion the inaccuracy of many of our young analysts is due to his lack of experience in making the determinations required, and to his work not being checked closely enough.

By making the analytical determinations an integral part of some process carried on by the student he checks his own determinations in a manner which is not possible by any other method. To illustrate, consider the manufacture of cement: if the student's analyses of the raw materials are not correct, this will at once be evident in the analysis and properties of the finished product. To my knowledge a very large amount of the work in quantitative analysis is at present given with no adequate check on the student's determinations, and even the instructor himself does not know the accurate com-

position of the material under examination by the student. In such cases what can we expect from the student?

Referring to my own work as a student, I find that the conditions mentioned in this paper regarding analytical work were quite prevalent. During my course in chemical analysis, I cannot recall a single occasion when my work was returned to me for correction and revision. At that time I ascribed this, of course, to my ability as an analyst; since then I have, however, changed my opinion very radically and would now ascribe it to the fact that the instructor did not know what he was handing me. In my own experience I never knew a student to make a correct analysis of such material as pig and cast iron, steels of all classes, minerals and ores, foods, or water, the first time he attempts the work with any one of these substances. If his work is arranged so that he himself will check the accuracy of his results, he may not have such an exalted opinion of his ability as an analyst, but he will know infinitely more about analytical chemistry.

The method of giving the laboratory course in industrial chemistry as heretofore outlined is, I know, faulty in many respects. The present outlined course only represents the evolution of our ideas up to this time.

We will undoubtedly find many places where improvement can be made, and this paper is presented with the belief and hope that it may bring out some suggested improvements.

A TOPOGRAPHICAL SURVEY OF RESERVOIR LANDS ON BROAD RIVER, SOUTH CAROLINA.

BY STANLEY DEAN.*

The survey to be described in this article was made in the spring of 1907, its object being to determine two things in regard to a proposed hydro-electric plant. The first of these was the acreage of the land that it was proposed to flood for a reservoir, and the location of all railroad lines, highways, buildings, and other artificial structures located within its limits. The second thing to be determined was the topography of all the land lying below the proposed high-water mark of the reservoir, so as to enable an accurate estimate of the water storage to be made.

It was proposed to build a concrete dam with its attendant abutments, gates, power-house, etc., across the Broad River at a point near Littleton, South Carolina, to back the water up to an elevation just below the tail water of another development, located about eight miles upstream, near Allston, South Carolina.

From the new plant at Littleton, it was proposed to transmit the electric power generated to Columbia, South Carolina, a distance of 22 miles, for the use of the cotton mills, electric street railways and other industries there located. In March, 1907, about one month prior to the making of the actual survey, the writer, in company with two other engineers representing New York and Washington interests, went over the development from Littleton to Allston, making an approximate estimate of the amount of power to be developed and storage to be secured. For this purpose, the data obtained from the United States Geological Survey Topographical Sheets and Water Supply Papers was used, the latter containing tabulations of the river discharge at Allston, where a government gauging station had been maintained for several years. At this time an examination was also made of the character of the foundations at the dam site, and accurate check levels were run from there to Allston in order to establish the exact amount of head available for the proposition.

The general features of the development, such as transmission lines, right of way, relocation of railroad lines coming within the boundaries of the reservoir, power market, and other commercial features were covered in the report to those financially interested, and were by them deemed sufficiently promising to justify further and more accurate investigation. The survey here treated of was the result of the conclusions

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based on this preliminary report. Having now briefly sketched the reasons for the making of this survey, the remainder of this article will be confined to the methods and practice followed on the same.

Extent of Survey:

The extreme height to which it was permissible to raise the water above the dam in times of high water was determined by the existence of a water power privilege above Allston, on which it was not allowable to encroach, and by the fact that a railroad bridge across the river at Allston Junction so narrowed the stream that it was not deemed wise to raise the water stage at that point. From these considerations, the height of the dam and the consequent flood line elevation were decided upon.

Organization of Party:

Two level parties, one on each side of the stream, were started from the proposed dam site to stake out the limiting contour of the reservoir at flood stage, which will hereafter be referred to as the flow line. The two parties worked upstream to Allston, where the flow line was confined between the banks of the stream, and there they checked in on a bench mark established at that point.

These parties were each followed by a transit party, which located the flow line just staked out, took topography, and located all property lines, buildings, etc., within and adjacent to the reservoir. The work done by these field parties was turned in to a drafting room established in Columbia, where notes were reduced and plotted and the map made, from which to estimate the acreage and capacity of the reservoir.

Level Party:

Each level party consisted of a levelman, recorder, rodman, and two axemen for clearing and making stakes. Starting at the bench mark previously established on the proposed line of the dam, the leader worked up to the flow line elevation furnished to him, and at the intersection of the dam line and the flow line, the rodman located a stake. The stake was about four feet long, three and a half of which projected above the ground, and one side of it was blazed and marked F1. The top of the stake was split and a small strip of white cloth was wedged into the opening to attract the attention of the transit party. At intervals along the flow line varying from about fifty feet on wooded or hilly ground to three or four hundred feet on open or gently sloping ground, flow line stakes numbered consecutively and marked with white bunting were driven. Flow line stakes were also driven on all fence lines where they were cut by the flow line.

In placing the stakes, the recorder calculated the difference between the height of instrument and the flow line and called it to the rodman, who set the target on the rod at that reading. The target when set was checked by the recorder. The target being thus set and checked, the rodman proceeded to the first point at which he deemed it necessary to place a stake, and moved the rod up and down the hill in obedience to the levelman's signals until the line of collimation cut the target, the bottom of the rod then being on the flow line. Here the axeman drove a stake while the rodman moved ahead along the flow line elevation until he reached a point for another stake.

Keeping the instrument a few feet above the flow line elevation wherever possible, the level parties marked out the line on either side of the river. Bench marks were established every half mile or less for the benefit of the following transit

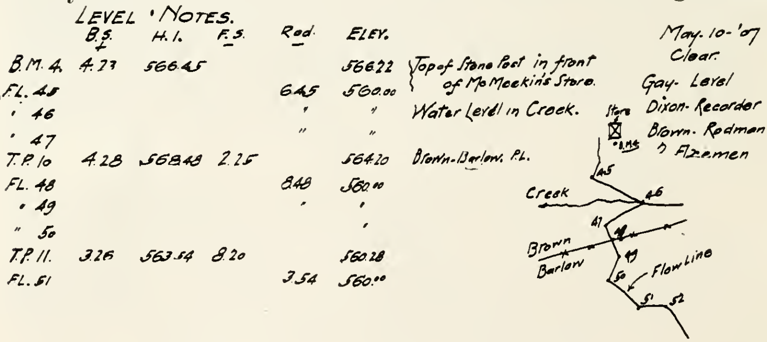


Fig. 1.

party, so as to give them a check on the elevations obtained by stadia work. Every night the transitman copied a list of all these bench marks and important turning points into his note book from the level notes.

To enable the transit party to locate the flow line, the axemen of the level party blazed enough trees along the line so that one could follow it through.

Fig. 1 shows a sample page from the note book, showing how the notes were kept and also a sketch of the flow line.

Transit Party:

Each transit party consisted of a transitman, recorder, one white rodman for picking out instrument stations and giving shots on the same, two colored rodmen for side shots and three colored axemen for clearing and stake making.

Starting at the proposed dam site, the transit party followed up the level parties, one on each side of the river, locating the flow line and all the property lines, houses, barns, roads, railroads, etc., and taking all topography below and adjacent to the same.

Setting up over a hub driven on the line of the proposed dam, the magnetic bearing of the line was observed, and the plates of the instrument were set to the corresponding azimuth, reckoning the south point as zero azimuth. The stadia method was used throughout for all stadia and side shots, and a sufficient number of the latter were taken to enable the contours of five-foot interval to be accurately drawn on the map from

TRANSIT NOTES

Obs	Dist.	Az.	Vert. Ang	Diffs. Elev.	Elev.
	At △ 42 - H.I. = 4.1			El. 528.27	
△ 41	422	326-42	- 0-42		
△ 43	300	198-10	+ 1-42		
△ 26 A	326	92-10	- 0-05		
FL. 11	180	30-00	- 0-25		
" 12	204	165-05	- 0-16		
	At. △ 26 A H.I. 4.7 El.				
△ 42	325	272-10	+ 0-03		
△ 25 A	242	262-15	- 0-10		
	At. △ 43. H.I. 4.9 El.				
△ 42	300	18-10	- 1-41		
FL. 14	72	280-04	+ 2-54		
△ 44	310	192-15	+ 1-05		
△ 19	582	264-32	+ 5-15		

Note:- Notes to be reduced by Draftsman in office.

FIG. 2.

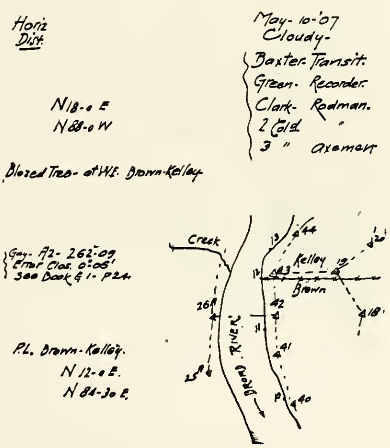


FIG. 2a.

the plotted points. In order to get all the topography between the flow line and the river, it was necessary in some places to run several lines approximately parallel to each other. This was due to the width of the reservoir, which in one place was two miles. These lines were tied to each other quite frequently by running cross lines along the property lines, the latter generally intersecting them at right angles to the general course of the river. At every tie in, the error of closure was noted, which, by breaking up the main traverse into small sub-traverses, gave a good opportunity to locate any error that might occur in the transit work.

A boat was kept on the river, and at several points where the stream was narrow, the shots were taken across the river for distance and azimuth by both parties, thus tying the work on the two sides together. Fig. 2 shows a sample page of transit notes, and Fig. 2a the sketch carried with it.

Drafting Room:

One draftsman was installed in the office of a local engineer at Columbia, with whom arrangements were made for the use of drawing tables. With the assistance of the chief of the party about one-third of the time, the draftsman was able to reduce and plot all notes for both transit parties.

Two sets of note books were kept by each transit party, one set being used in the field, generally for a period of one week, while the other set of notes were in use in the office. An exchange of books between the office and field was made at each week end. The field parties were not required to do any work on the books at night, such as reducing notes, etc., the only work of this nature done by them being on rainy days, when it was not possible to work outside.

TRAVERSE CALCULATION & ADJUSTMENT. — RESULTS TO BE USED TO PLOT STATIONS.

Sta.		Reduced			Lat. D		Long D.		Corrected Lat. D		Corrected Long D		Difference of Elevation		Corrected Diffs. of El.					
From	To	Dist.	Az.	Brg.	N+	S−	E+	W−	N+	S−	E+	W−	+	−	+	−	Elev.n	Sta	Latitude	Longitude
26	27	426	92-10	N87-50W	21.0			4258	210			4262	425		430		56725	27	+ 2641.0	− 1058.8
27	28	500	180-10	N0-10E	500		15		4997		15		262		265		5699	28	+ 3140.7	− 1067.3
28	29	325	160-00	N20-0W	305			1108	3047			110.9		12.09		12.06	55784	29	+ 3445.4	− 1178.2
29	30	376	185-30	N5-30E	3745		360		3742		360			328		324	55460	30	+ 3819.6	− 1142.2
30	31	710	271-38	S88-30E		196	7098			196	7092		217		219		55679	31	+ 3800.0	− 433.0
31	32	850	339-25	S20-35E		7952	2990			7958	2980			12.62		12.47	54432	32	+ 3004.2	− 134.2
32	26	637	62-55	S62-55W		3840		5080		3842		5088	1850		1863		56285	26	+ 2620.0	− 642.6
					1200.5	11988	10463	10446	11996	11996	10455	10455	27.54	27.99	2777	2777				

The Armour Engineer

FIG. 3.

On receipt of the note books containing the previous week's work, the draftsman prepared a table of stadia shots for all traverses closed by both parties. Fig. 3 is a copy of such a traverse closure and adjustment. In preparing this table he first reduced all the station stadia shots to corrected horizontal distances and differences of elevation, using Cox's Circular Slide-Rule Stadia Computer for this work. He then calculated the latitudinal and longitudinal differences of all courses in the various traverses, making a separate calculation and adjustment of the error of closure for each traverse and distributing the error in direct proportion to the latitudinal and longitudinal differences of each course. No courses were weighted, as it was assumed that the same chance of error prevailed for each course.

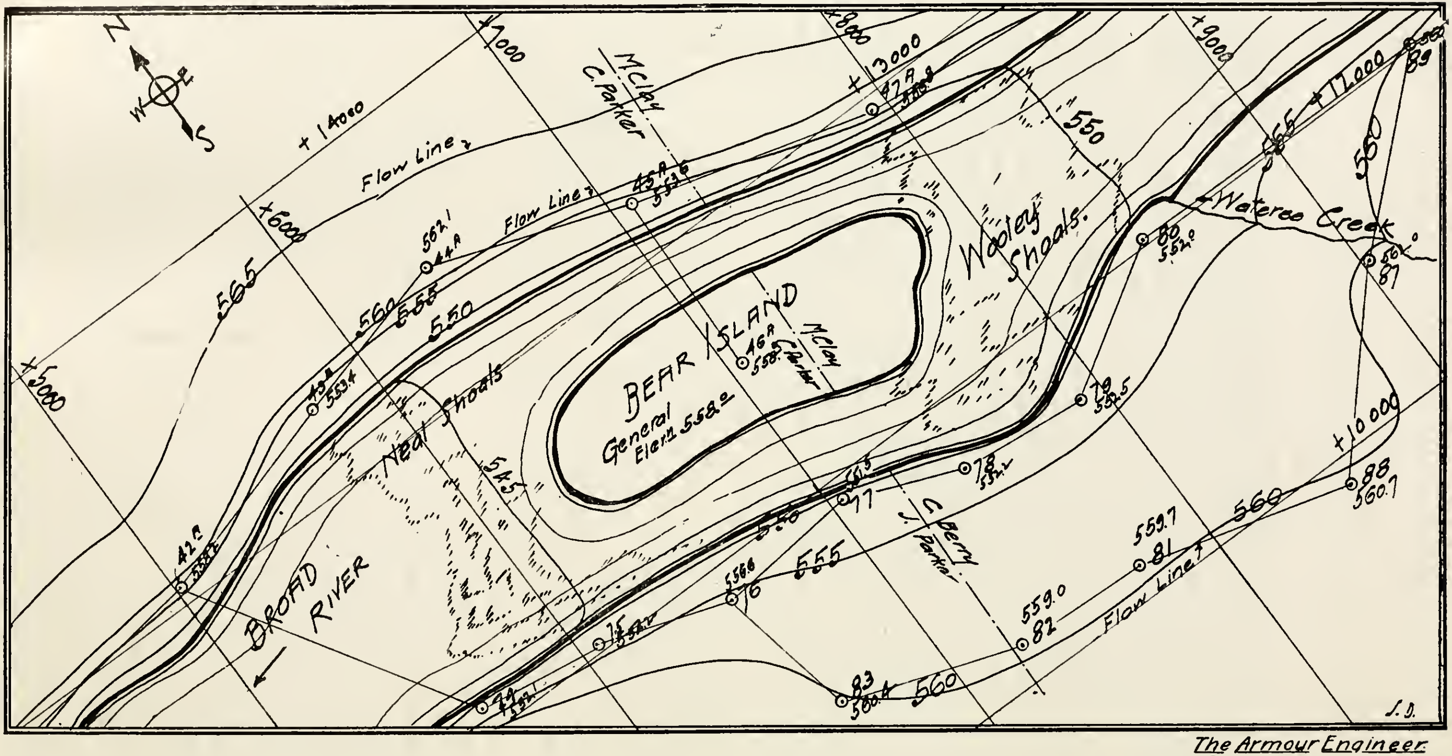
Having adjusted the traverse for horizontal error, the draftsman next adjusted the traverse for vertical error of closure, making the elevations agree with the shots taken on

the bench marks and turning points left by the level party, and starting afresh from these to continue adjusting station shots until another bench mark or turning point was picked up by the transit party. As was previously stated, the transit party was provided with a list of the bench marks and turning points, enabling them to locate the same.

Having adjusted all the traverses in both the note books, the draftsman next plotted them on detail paper to a scale of 200 feet to the inch. In plotting the station shots by latitudes and departures, the detail paper was laid out in squares of north and south, and east and west lines, 1000 feet apart, (five inches on the map) and each line numbered with its co-ordinate number. (See Fig. 4.)

The instrument stations were next plotted on the map from the nearest co-ordinates, and their numbers and elevations noted thereon in red ink. Having thus plotted the traverses, the draftsman reduced all side shots for distance and elevation, and plotted them from the stations. For plotting the side shots, a full circle bristol board paper protractor, graduated to 0°-15′, and having a diameter of about 20 inches, was used. The circle was marked from 0 to 360° in an anti-clockwise direction, the quarter sector between 270° and 360° being cut out except for a strip around the edge containing the graduations. Distances to the scale of 1″-200′, the same as that of the map, were marked on the edge of the protractor where the section had been cut out, from the center to the zero point on the circumference.

To use this protractor, a north and south line was drawn through the station from which the notes were to be plotted, and the center point of the protractor was placed over the station. After sticking a pin through the center of the protractor and through the station, the former was left free to revolve about its center. Now, when the zero mark on the protractor coincides with the line drawn south from the station, the scale reads south or zero azimuth. By turning the protractor to the right about its center until the circle graduation on the protractor corresponding to the azimuth of the shot to be plotted coincides with the south line, the zero mark on the protractor points in the direction of the azimuth of the shot, and it is only necessary to mark the point on the paper at the right distance on the scale. The shot is marked with a point in a small circle, and the shot number is noted together with its elevation and any descriptive remark, such as "foot of slope," "water's edge," etc., for which appropriate abbreviations were provided.


N
S
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E
BEAR ISLAND
General Elev. 558.0
Wooley Shoals.
Neal Shoals
BROAD RIVER
Wateree Creek
Flow Line
Flow Line
Flow Line
M'Clay
C. Parker
M'Clay
C. Parker
C. Berry
J. Parker
+ 14000
+ 13000
+ 12000
+ 10 000
+ 5000
+ 6000
+ 7000
+ 8000
+ 9000
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J. D.
The Armour Engineer.

FIG. 4.

The draftsman and one helper were able to reduce about 300 side shots per hour and to plot about 150 shots per hour on the map. For the draftsman working alone, the time was of course more than doubled.

When the shots were all plotted, the property and fence lines, houses, barns, roads, railroad lines, etc., were drawn in with the aid of the note books, sketches, and remarks, and the contour lines of five-foot interval were sketched in. This work was first penciled in detail, and later inked in.

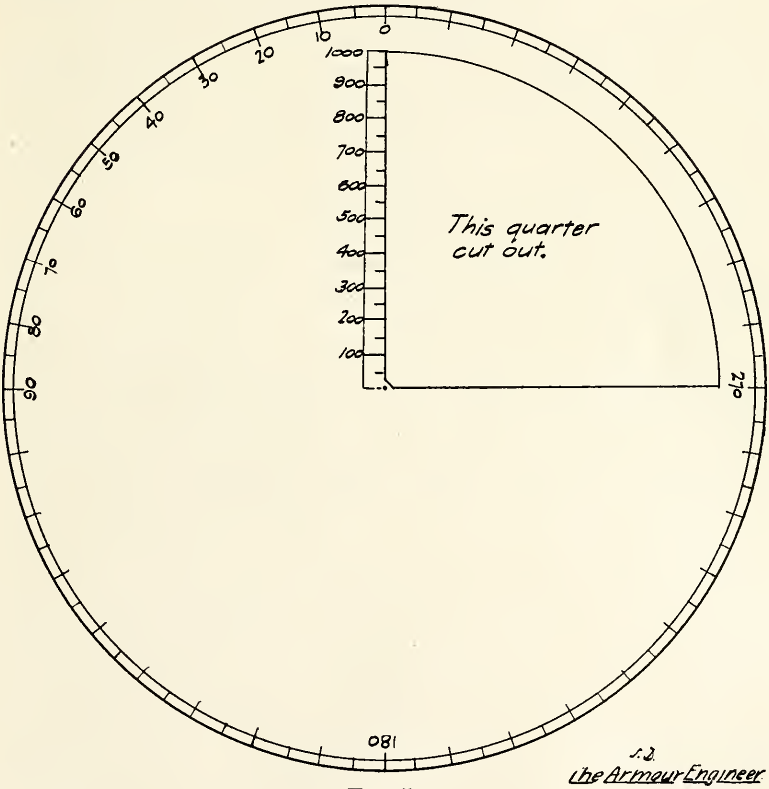

Fig. 5.

On completion of the map, the area of each parcel of land lying between the flow line and the river's edge was determined by going over the same three times with an accurately checked and adjusted planimeter, the mean of the three readings being taken as correct. This method saved much time over the method of calculation of areas by latitudes and

departures, and was quite accurate. The area of each contour line in the basin was similarly determined, and an accurate estimate of the storage capacity of the reservoir was made therefrom. Tracings were made of the completed map with all land areas and storage capacities tabulated thereon, from which blueprints were made later.

General Remarks:

Before starting the survey, all instruments were carefully checked for adjustment and accuracy of stadia wire intervals. No correction was made in reducing the stadia notes for the stadia constant (f+c), the practice being for the instrumentman to read to the nearest foot above the wire. That is to say, if the stadia reading was 121.4, it was read as 122, and was so recorded. When the distance exceeded two or three hundred feet, a reading could not be made closer than within one foot, and the reading was recorded as read by the observer to the nearest foot. Wherever there was a chance for doubt, however, the large reading was always taken.

The results obtained showed the reasonableness of this method, as the errors of closure were remarkably and consistently small for such work, the errors varying from one in 1500 to 2500 throughout the survey.

Great care was exercised by the instrumentmen on station shots, the same being read both forward and backward for distance and vertical angle. That is, going forward from station 25 to station 26, the reading was 216 feet distance and —2°-14′ vertical angle. When the instrument was set up at station 26 and oriented with the correct azimuth to station 25, the distance was read as 215 feet and the vertical angle as +2°-16′, and thus recorded. The mean of the forward and backward shots was then taken, unless one was read against the sun, in which case the recorder accepted the shot taken with the sun on the rod, and corrected the other to agree. The draftsman was not permitted to change any distances or other notes without first referring the same to the chief of the party.

On all forward station shots, the needle was read for a check on the azimuth, and the reading recorded on the right-hand page of the note book. For instance, when set up on station 25 and sighting forward to station 26, the azimuth is 140°-27′, and the needle reading is N 39°-30′W. This should invariably be done, as it furnishes a rough check on the transit work when the needle is not subject to local attraction, and gives a chance to detect an error in the field. It is thus possible to check over the work, should an error be suspected from a continued disagreement of the needle and the azimuth, without allowing the party to complete the traverse and find an angular error of closure somewhere in it.

The adjustments of all instruments were carefully checked up about once a week when running without mishaps, and in the event of an instrument receiving a jolt, an immediate stop was made to check up its adjustments. After the first thorough adjustment at the start of the survey, however, no adjustments were found necessary on the entire survey occupying two months time, the instrumentmen having been instructed not to change the adjustment for a very slight error, as it was believed that more harm than good resulted from the policy of continually tampering with the instrument adjustments.

No work was required of the field parties at night or on Sundays, as the writer believes that ten hour's work constitutes a day for outside work, and that better progress can be made on such a schedule than by working longer hours and seven days a week. The writer would emphasize this last point, as it has been his experience that a large number of engineers think otherwise. Aside from any ethical standpoint, he is fully convinced of the futility of long hours and Sunday work.

As a large part of the area surveyed was adjacent to plantations, arrangements were made for the housing of the field forces there, it not being considered best to install a camp outfit for the short time that it would be in use.

The writer had charge of the survey and investigation for Viele′, Blackwell, and Buck, Consulting Engineers, of New York, and spent about two-thirds of his time with the field parties, the remainder being spent in the office on the map work and in assisting a local legal firm in the investigation of land titles, etc.

INCREASING BOILER FURNACE EFFICIENCY.

BY C. E. BECK.*

The increasing of boiler furnace efficiency has been a topic of great discussion among engineers and boiler manufacturers, especially since the steam engine has practically reached its height of perfection. A topic more worthy of investigation and interest could not be selected by an engineer.

How shall we proceed to build up the efficiency of boiler furnaces, or in other words, how shall we aim to cut down our coal bills? We must have a starting point or some criterion to begin with. We know that combustion is incomplete without a sufficient amount of air, and since too great an excess of air cools the products of combustion, it is evident that the most efficient furnace is the one that completely consumes the combustible with the smallest excess of air. No matter how we proceed, whether we consider fuels, methods of firing, draft, or what not, we are brought back to the supply of air.

It is the writer's purpose to show how gas analysis may be applied to any question relative to furnace efficiency. It is not necessary to treat the theory of combustion, as there is but one gas that we need consider. The product of complete combustion is carbon dioxide, CO_2, and in combustion, this CO_2 is yielded from the carbon of coal, its chief constituent. If we assume that the coal is all carbon, a given weight of coal should produce a given weight of CO_2, and since the atmosphere contains 20.7 per cent of oxygen we should get 20.7 per cent CO_2 in complete combustion, although this is impractical in furnace work.

In ordinary furnace work the excess air employed is about 40 per cent, which of course dilutes the CO_2 and consequently reduces the percentage of CO_2 in the escaping gases. This excess air absorbs heat energy and carries it up the chimney. The heat thus absorbed is an utter loss and will represent about 10 per cent of the heat of the fuel. A gas analysis under such conditions should show about 14 per cent CO_2, though it is evident that if we increase the air supply we cut down the CO_2 and increase the loss in fuel. The greater number of losses due to faulty furnace operation are accounted for by the excess of air. Excess of air will cause bare spots in the grate, which are far worse than to find combustible in the ash. We may also find combustible in the stack, which is evidence of wasted energy; but if we are looking for sick furnaces we must examine the clear as well as the smoky stack. Coke and anthracite or a coked fire of bituminous coal do not produce smoke, yet the chimney gases may be full of combustible gases.

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*Class 1911. Mechanical Engineering, Armour Institute of Technology.

We may now say that low CO_2 may be caused by either an excess of air or incomplete combustion, both of which may occur simultaneously. We may also find carbon monoxide, CO, in the presence of a high percentage of CO_2, but this is usually caused by a lack of proper conditions for complete combustion, and by improper furnace design. We must, of course, have an excess supply of air in order to get combustion that is anywhere near complete, and as we have settled upon flue gas analysis as a means to build up the boiler furnace efficiency, we will provide ourselves with a simple Orsat gas analyzer. A thermometer for measuring stack temperatures is necessary, while a draft gauge is indispensible.

In our building-up operations it is most natural to determine air leakage first. We will do this by comparing the per cent of CO_2 at the breeching with that at the furnace, and even if the difference is only one or two per cent, it is quite evident that air leakage is present. A displacement vessel of some sort is usually connected with the breeching and the gases drawn into this vessel for a period of, say, half an hour. In the meantime a man with the Orsat instrument should be analyzing samples taken from different points in the different passes of the boiler. He does this by passing a small pipe through the side wall and taking samples at various distances from the wall.

At the end of the run the gas in the sampling vessel is analyzed, and if its percentage of CO_2, when compared with the average of that taken in the passes, is found to be less, the loss can be attributed to the infiltration of air. The average percentage of CO_2 at the different passes should now be examined and the differences will indicate about where the leaks are. The nearer the air leaks are to the furnace the more damage they will do, as the air is then longer in contact with the heated surfaces of the boiler. It is now our duty to find the air leaks. We must look over the entire setting, and examine the blow holes and clean-out doors. If the boilers are set in batteries, the walls between them should be examined at some time when the boiler on either side is dead. We may find that we are drawing air in through these dividing walls, which are usually poorly constructed. These leaks are plugged up, and another analysis is made as before. The difference found will be chargeable to air leakage.

The mere plugging up of large openings is not sufficient to obtain the best results, as it must be remembered that the pressure inside a boiler furnace is below that of the atmosphere. The whole setting should be sized with glue, which, when dry, should be covered with a heavy coat of asphalt or fire-proof paint. Do anything to keep the heat in and the air

out. After all leaks are stopped we can turn to the question of how much air to admit through the ash doors in order to obtain the maximum percentage of CO_2. This can be done by first cutting down the air supply, and then gradually increasing it until the percentage of CO_2 is a maximum throughout the furnace. At this point it will be found that we are admitting about 40 per cent more air than is theoretically necessary.

Another question which is often met with in practice is, whether or not to consider the percentage of CO_2 at the breeching as the actual amount being formed in the furnace. If we are absolutely positive that all leaks are plugged, the per cent of CO_2 at the breeching may be taken as correct; but suppose we analyze the gases at the breeching and find 5 per cent CO_2, and then test the gases taken from the first and second passes and find 10 and 12 per cent respectively. This difference would surely indicate leakage into the breaching which is very often the case with a new setting.

We might now turn to the question of draft, which in some respects may be considered the most important in boiler furnace operation. We are concerned in saving fuel, and we should put some control on the effect of the chimney. We must do this in an intelligent manner, and again our gas analyzer must be applied. We will first note the appearance of the fires, the position of the doors admitting air to the grates, and the position of the damper. We will now change the draft about one-tenth of an inch of water, and analyze the gas. If we find that we have increased the CO_2 we may know that we are progressing in the right direction. In changing the draft it is more advisable to make the change with the damper than with the ash-pit doors, as changing it with the ash-pit doors enhances the tendency for air leakage by increasing the draft pressure at other places where air may enter.

Methods of firing, quality of coal, design of furnace and many other things are factors in boiler furnace work, but the writer has considered most of these conditions as being practically ideal, since it is more general among firemen to consider most everything but flue gas analysis when attempting to build up furnace efficiency.

SOUTH KEDZIE AVENUE (CHICAGO, ILL.) REINFORCED CONCRETE ARCH BRIDGE.

BY JOHN C. PENN.*

The proposed through routing of the street car line on Kedzie Avenue, Chicago, Ill., and the constantly increasing traffic on this highway necessitated the renewal of the bridge over the Illinois and Michigan Canal. The old steel span at the site was erected in 1880 and was sadly in need of repair.

The traffic over the bridge is not very heavy, but it would have to go several miles out of the way if the span were entirely removed, so a temporary bridge was necessary. The city plans contemplated the building of plank roadway approaches about 70 feet to the west of Kedzie Avenue and the moving of the old span parallel to itself between these timber approaches, either by scow or by skids. The contractors, however, figured that they could better and more cheaply build a new roadway on a few pile bents, than take the risk of moving the shaky old span. Since an opening of only 18 feet was required by the canal commissioners, the contractors were allowed to go ahead with their plans. The temporary bridge was started July 19 and finished August 4, 1909. About 32,000 feet (board measure) of timber were used in the approaches.

The arch bridge, now completed, has an extreme length of 140 feet and a width of 38 feet from center to center of hand railing. A roadway 24 feet in width and two sidewalks are provided for. The arch is built on a skew of 68° 30′ in the general direction of the canal and has a span of 75 feet, with a rise of 15 feet. Each abutment foundation covers an area of approximately 39 by 25 feet, and extends to a depth of —12 feet, C. D., on the canal face, stepping up by 4 steps to an elevation of —7.5 feet, C. D.

The springing line of the arch is at +3 feet, and the highest point of the roadway in the center of the bridge is +20.67 feet. A towpath is provided through the wing walls of the north abutment by means of an arch opening of 7 feet in width. Four spandrel walls, two on the outside and two intermediate ones, are built directly on the arch ring. The outer spandrels support the cornice, railing, pedestals, and the outer edge of the sidewalks. The combined gutter and curbs, and the inner edge of the walks, rest on the intermediate spandrels.

Permission to use the ground to the east of the bridge could not be obtained, so that the contractor's plant was squeezed between the new bridge and the temporary bridge. They erected two derricks with 60-foot booms just to the west

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*Class 1905. Assistant Engineer, Bridge Department, City of Chicago.

of the bridge. These derricks could reach practically every corner of the job. On a deck scow, tied up between the derricks, a yard mixer of the Smith type was set up. Runways from this platform to the shore gave access to the sand and gravel piles on the north approach. The cement shed was

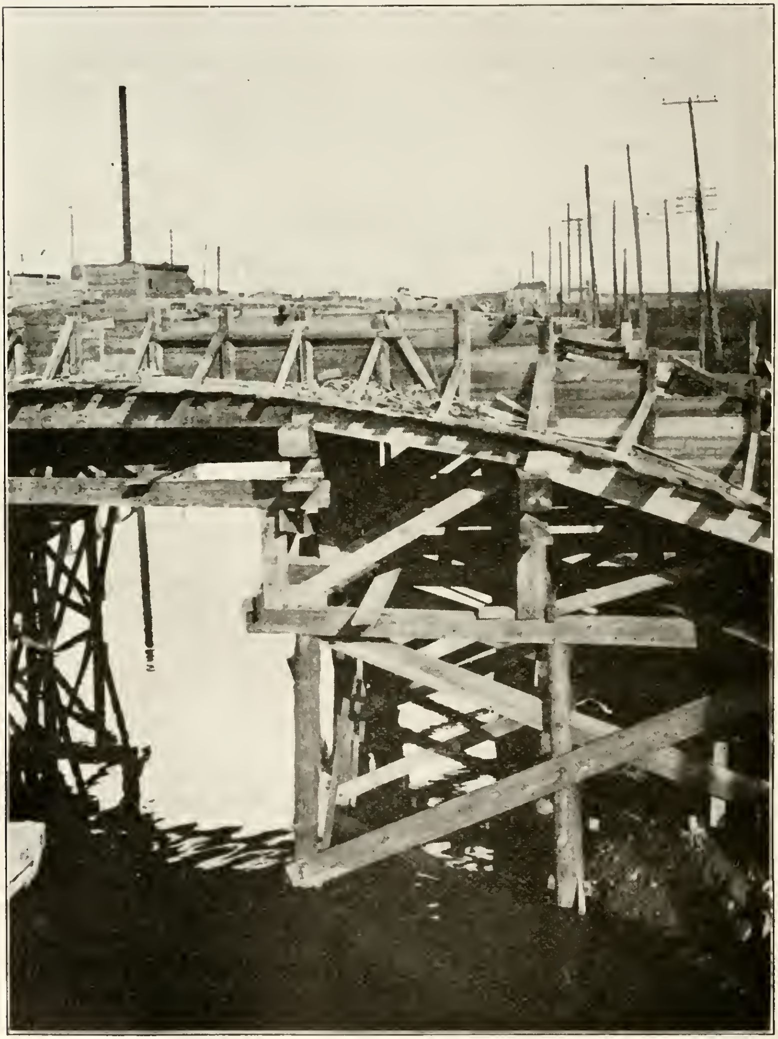

Fig. 1. View of Piles and Bents Showing Arrangement.

erected on the north end and was also connected with the mixer by a runway. With the excavated material dumped at each end of the bridge the contractors were very often in cramped quarters.

Along the east side of the bridge and 18 inches from its face are the two overflow outlets of the Kedzie Avenue sewer. These outlets are connected by an inverted siphon five feet in diameter under the Illinois and Michigan Canal.

The soil in this locality is a blue clay mingled with a great deal of fine sand. As long as the stuff remains dry it is comparatively easy digging, i. e., with dynamite, pick and shovel. Excavation was started on the north side, being carried out to the neat line of concrete. Some of the dirt was dumped on the canal face to keep out the water of the canal. When excavation had been carried to an elevation below the siphon

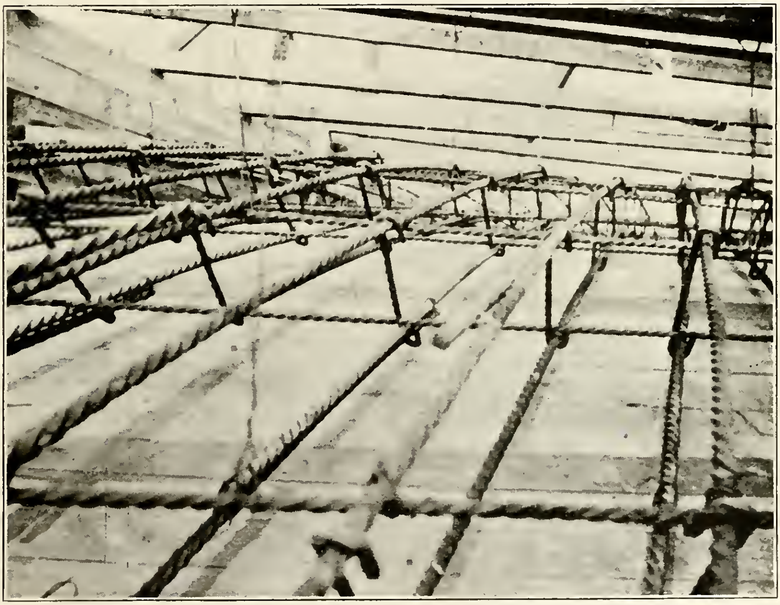

Fig. 2. Showing Spacing of Twisted Reinforcing Bars.

of the sewer, water appeared, and at first it was quite difficult to tell where the water came from. After experimenting with paint, however, it was proved conclusively that it came from the sewer. It was then easily taken care of by pumping out the siphon of the sewer, and the sewer was dammed up on each side of the canal. But the occasional filling up of the excavation caused a great deal of trouble. The instant the dirt came in contact with water, the clay dissolved and became almost a semi-liquid. The excavation on both sides of the canal was carried on under the same difficulties.

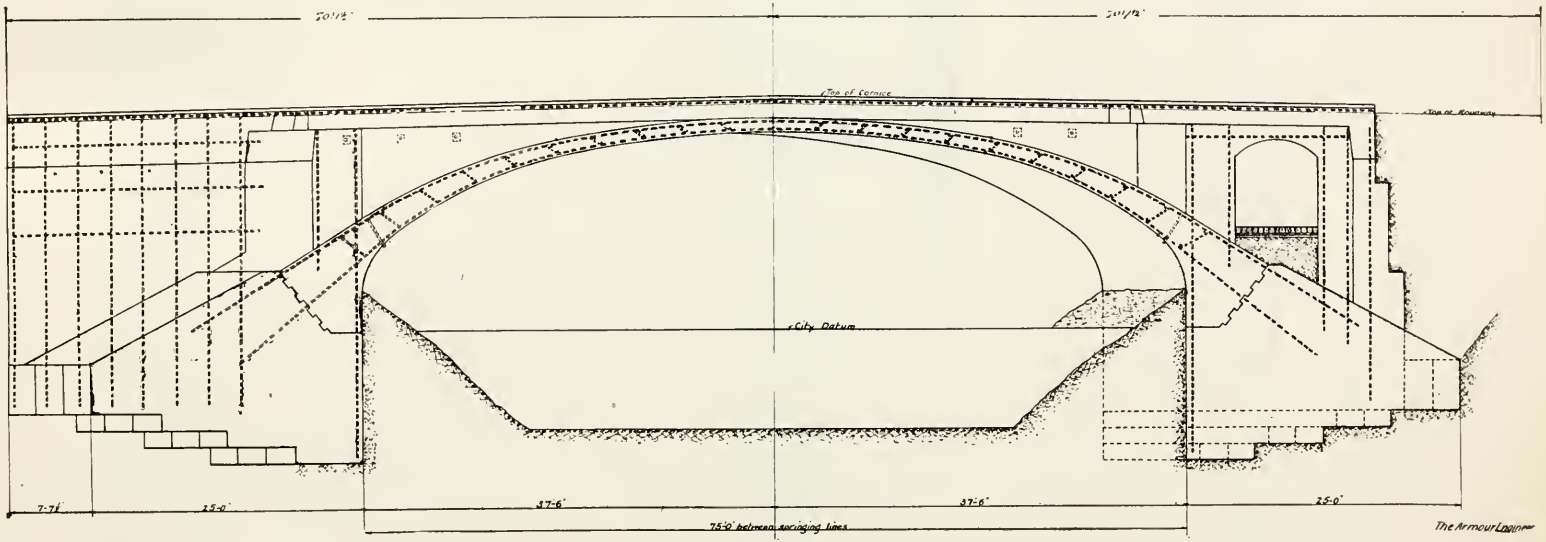

Fig. 3. Longitudinal Section at Center Line of Bridge.

For the falsework, short piles were driven in bents parallel to the direction of the canal, an opening of 18 feet being left in the center of the canal. The piles could not be driven in very straight rows, so that 12 by 12 inch caps were placed on them at the same elevation wherever possible. Upon this table, accurately spaced bents, parallel to the direction of the canal, were constructed. Upon these bents 2 by 12 inch stringers cut from patterns were placed, spaced 12 inches center to center. This gave the curve of the arch very accurately. Dressed and matched lumber placed upon this gave a very smooth surface. The arrangement of the piles and bents is shown in Fig. 1.

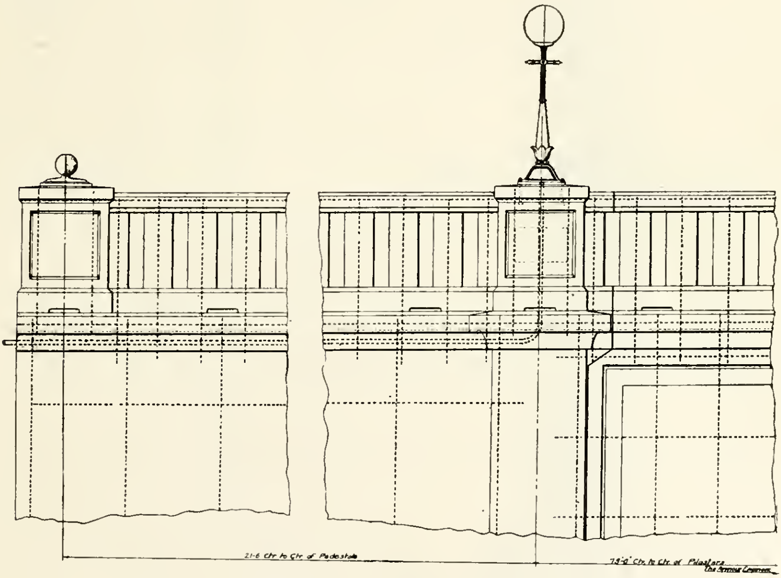

Fig. 4. Elevation of Hand Railing and Pedestals.

Some fourteen tons of twisted bars are imbedded in the bridge. In the arch proper they are spaced 1 foot apart, one above the other, as is illustrated in Fig. 2. Splices are alternated by using various lengths for the rods.

Three different kinds of concrete were specified. A 1:3:5 mixture was called for in the foundations up to the skew backs. The arch proper, spandrel walls, sidewalks and curbs are built of a 1:2:4 mixture. The railing, cornice and ornaments are made of a 1:2:3 mixture, using roofing gravel for

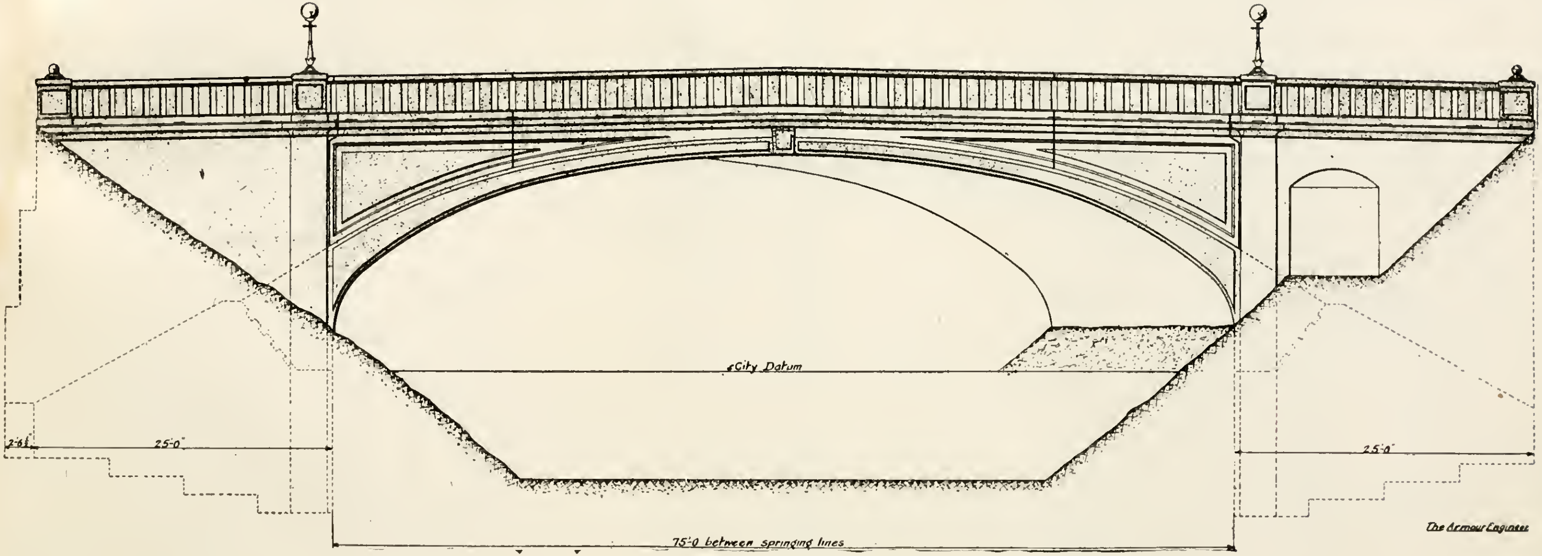

FIG. 5. ELEVATION.

the coarse ingredient. Gravel was used in the remainder of the bridge. Two-inch dressed and matched lumber was used for the forms. Bracing was usually done from the outside, although wire and rods through gas pipes were used in several places.

When the foundations were ready and the proper forms in place, the arch wing was concreted. The entire width was divided into three parts, and one of these sections was completed in one day of nine hours. About twenty-five men put in some 113 cubic yards of concrete in that time. The arch

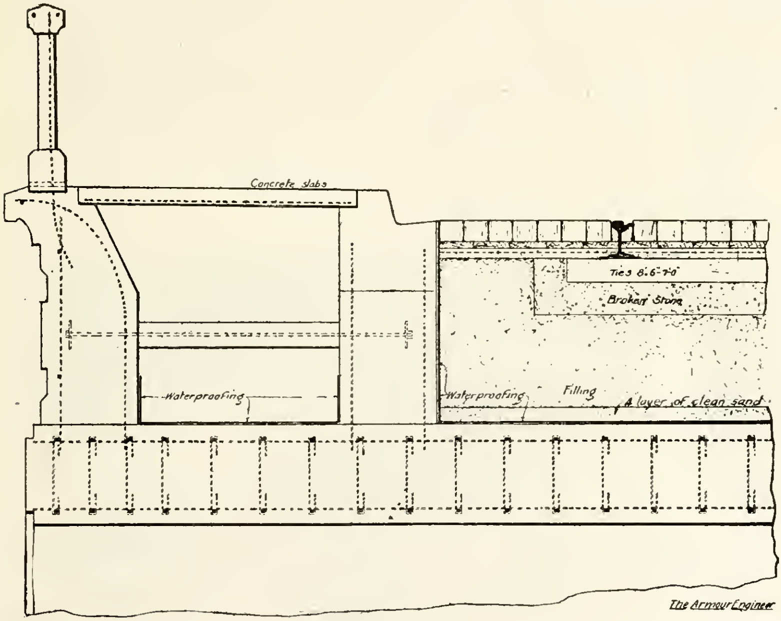

FIG. 6. GENERAL CROSS SECTION THROUGH HAND RAILING, SPANDREL WALL AND ARCH RING.

rods were supported by wires from above and gave very little trouble except to bark the laborers' hands and shins. The concrete was put in rather wet and all outside surfaces were spaded.

The abutment walls, parapets and spandrel walls were next built in the order given, and all concrete brought as high as the cornice. The ornamentation on the bridge, the cornice, and the railings, are of very simple design and were easily constructed by using the proper mouldings. In the cornices and wherever spading could not be done, mortar was first plastered

on the inside of the forms and the concrete was placed against the fresh mortar. The entire railing was build in place. For the balustrades, two parallel faces were built of dressed and matched lumber and stops fitted in between these at the proper distances. All horizontal surfaces were finished off with the trowel.

Wrought iron pipes for drainage were built through the arch ring, leading from the upper surface to the inner faces. The upper side of the arch and the inner sides of spandrel walls and parapets were waterproofed with "Sarco," so that ample drainage is provided for the filling on the arch.

Fig. 7. Kedzie Avenue Bridge, Looking Northeast.

The excavated material was used for backfilling on the arch. It was well puddled and seems to hold out well, as the street car men have placed the double track and the temporary cedar block paving upon it. The work was finished on December 18, 1909.

Four expansion joints were built in each spandrel wall, two over the springing lines and two at the quarter points. All rods except those in the upper railing were cut at the joints. During the last cold snap, the joints over the springing lines opened up fully one-eighth of an inch. Even those in the upper hand-rail opened up that much, but neither rods nor concrete seemed to be affected.

The falsework at the crown was built one and one-quarter inches too high, to allow for settlement. The arch is now within one-quarter inch from its figured position. With the cold weather it may have been exactly correct.

The forms were removed very carefully and all rough spots were scoured with emery bricks. A very fine surface on all visible faces has been produced without much trouble or expense. Were the bridge located in some small park or in a more aristocratic neighborhood it no doubt would be called a handsome concrete structure.

The bridge was built by the FitzSimons & Connell Company of Chicago at a cost of about $23,000.00 to the city. Thos. G. Pihlfeldt is engineer in charge of the Division of Bridges and Harbor, and C. S. Rowe has charge of all construction. The writer was in local charge of construction.

DIAGRAM OF THE FLOW OF WATER IN OPEN CHANNELS.

BY HARRY W. YOUNGBERG.*

The diagram shown herewith is an approximate solution of the Kutter and Chezy formulæ. It is believed that in no case will the result obtained from the diagram vary more than 5% from the quantity given by solving for c in the Kutter formula and substituting its value in the Chezy formula. When it is remembered that the value of n is chosen with some uncertainty, and that all results obtained from formulæ are increased in water calculations, the error is negligible.

To get a basis for the diagram, the Kutter formula is transformed as follows:

$$c = \frac{\frac{1.811}{n} + 41.65 + \frac{.00281}{s}}{1 + \frac{n}{\sqrt{r}}\left(41.65 + \frac{.00281}{s}\right)}$$

$$c = \left(\frac{\frac{1.811}{n} + 41.65 + \frac{.00281}{s}}{\frac{\sqrt{r}}{n} + 41.65 + \frac{.00281}{s}}\right)\frac{\sqrt{r}}{n} = k\frac{\sqrt{r}}{n}$$

$$\therefore \text{velocity} = c\sqrt{rs} = \frac{r\sqrt{s}}{\left(\frac{n}{k}\right)}.$$

When $s = .00005$, $$k = \frac{1.811 + 97.85\,n}{\sqrt{r} + 97.85\,n}.$$

When $s = .01$, $$k = \frac{1.811 + 41.93\,n}{\sqrt{r} + 41.93\,n}.$$

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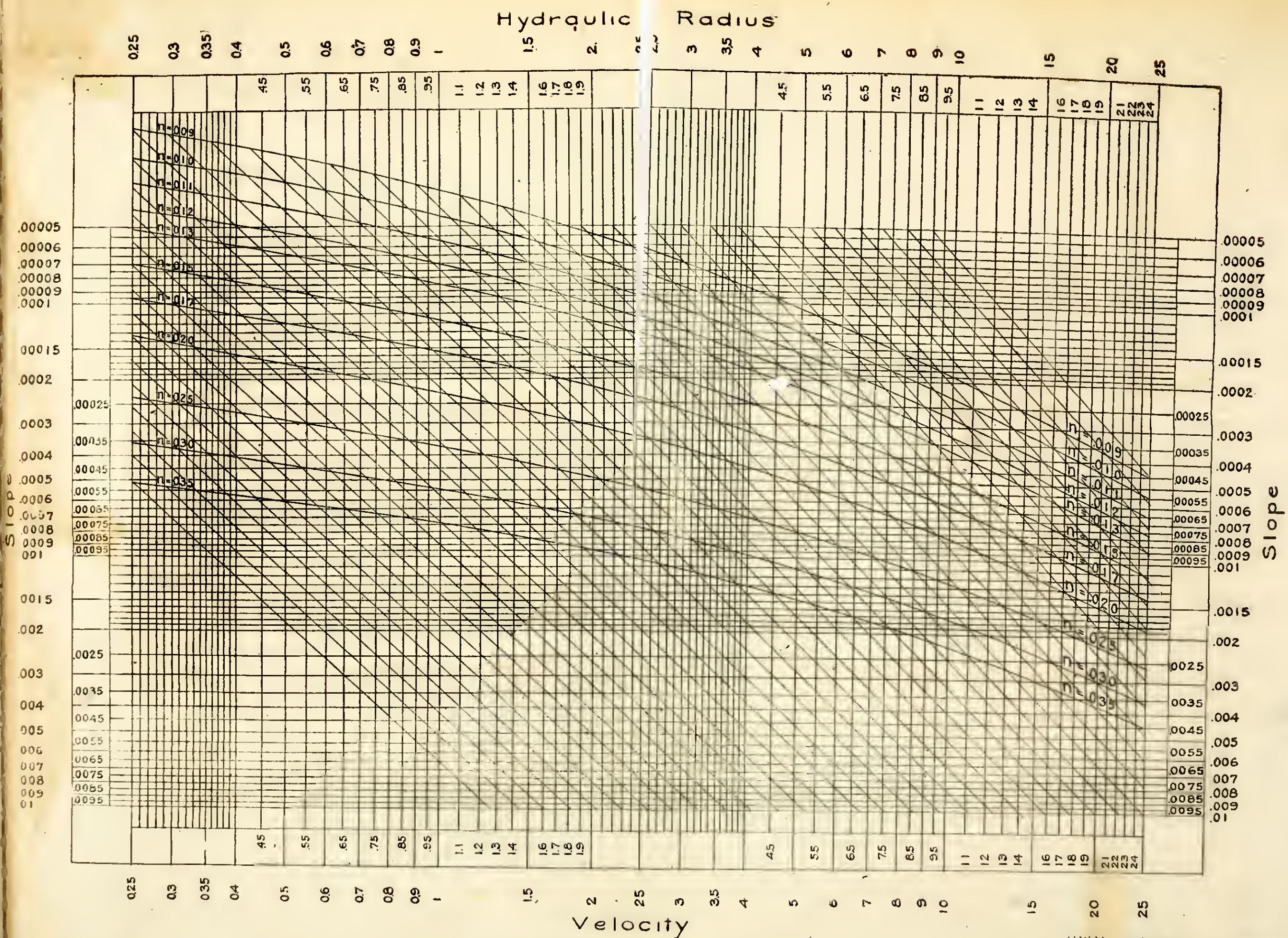
*Class 1909. Civil Engineering, Armour Institute of Technology.



H W Youngberg
The Armour Engineer

Diagram of Flow of Water in Open Channels.

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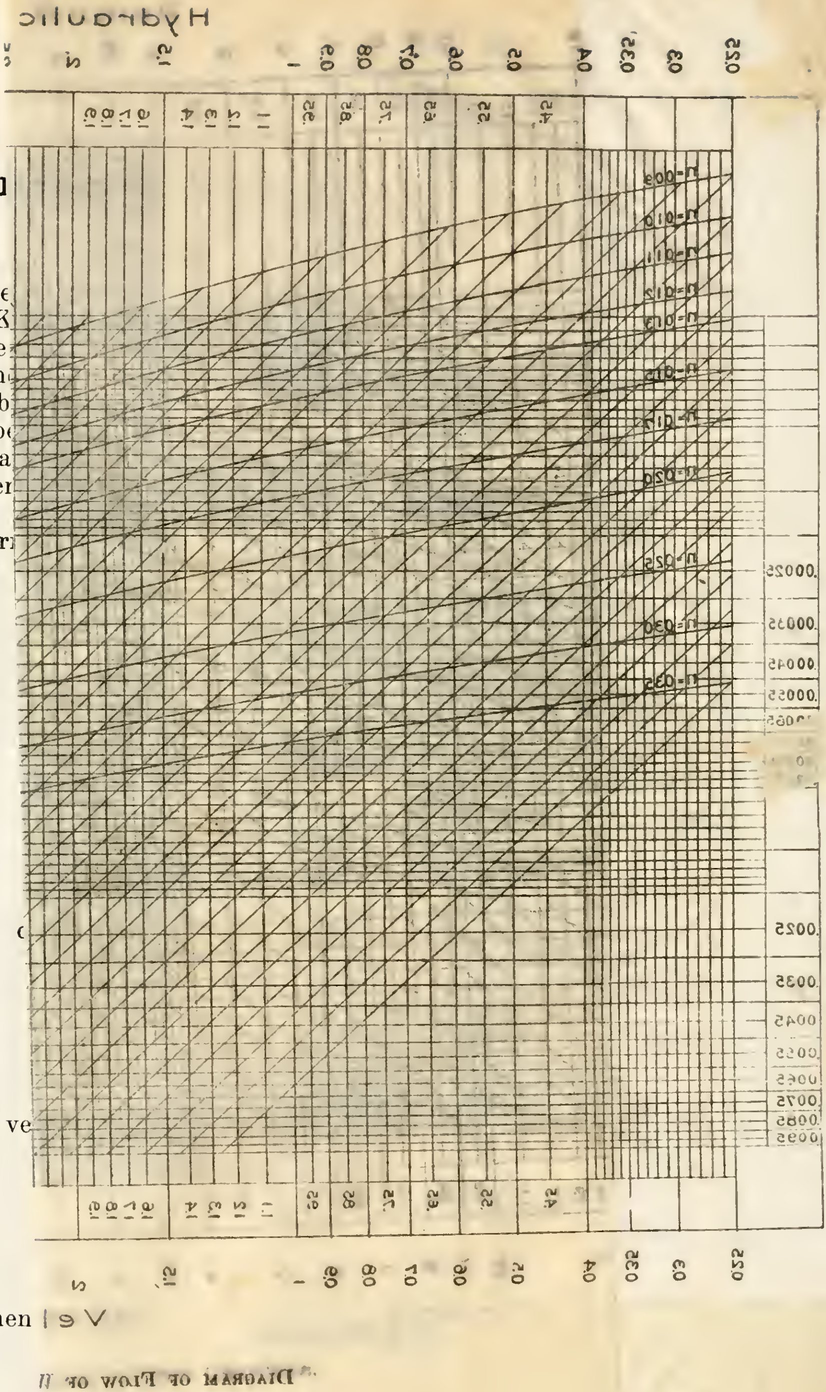

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The values of k in the above expressions were determined for numerous values of n and r, it being assumed that k varied with s uniformly between the values s = .00005 and s = .002, which was not in error to a greater extent than the 5% previously mentioned.

By laying out the logarithm of r horizontally, the logarithm of $\frac{n}{k}$ vertically on the left and the logarithm of $\sqrt{s}$ vertically on the right, a 45° line drawn upward to the left will give $\log r + \log s - \log \frac{n}{k}$ which equals logarithm of the velocity on a horizontal line. Having two values of k for each value of r and n, the oblique line varies from 45°, to approximate the effect of s on the value of c. After a sufficient number of points from $\frac{n}{k}$ had been plotted, a curve was drawn and given the corresponding value of n. The table is adjusted so that the same scale reads hydraulic radius and velocity.

The intersection of r with n, and s with v, must lie on the same oblique line.

Example 1.—Given a channel lined with cement mortar, the hydraulic radius being .34 feet and the slope .0011. Find the mean velocity of the water.

From the intersection of the vertical line through .34 with the curve corresponding with n = .0011, follow the inclined line to the horizontal line marked s = .0011; then the vertical at this point indicates the velocity to be 2.1 feet per second.

Example 2.—Given a channel in firm gravel, the hydraulic radius being 14 feet. Find the slope necessary to produce a velocity of 4 feet per second.

From the intersection of the vertical through 14 with the curve n = .020, follow the inclined line upward to the vertical marked 4, and read the slope on the horizontal line equal to .000077.

Example 3.—Given the velocity of a stream equal to 1 foot per second, the slope .002, and n = .030. Find the hydraulic radius.

From the intersection of the vertical line through 1 and the horizontal line through .002, follow the inclined line upward to the curve n = .030, and read the hydraulic radius on the vertical as .43 feet.

HIGH SPEED STEEL AND ITS HEAT TREATMENT.

BY W. G. SMITH, M. E.*

Not so many years ago an instructor in forging would begin his advice to his students with the (then) sage exhortation, "Never work your iron cold and never work your steel hot." The idea was that steel was ruined by heating beyond a cherry red, therefore all the forging of steel must be done below that point. This made steel forging a troublesome process, because the low heat allowed it to remain hard and unyielding to the hammer and in addition made much and frequent re-heating necessary.

This condition is now completely changed, and many other revolutionary features have appeared with the advent of the new tool steel, called High Speed Steel, which, as we shall see, has been brought about by the addition of the rather rare metal tungsten to the chemical composition of steel. Let it be understood that High Speed Steel is essentially a cutting steel, and is only used for that purpose. The common steel is much more practicable for structural purposes, and for shafting, holders, and other tools which are not used for cutting metal.

History of Tool Steel:

Steel is a mixture of iron and various other elements, used in widely varying quantities. When heated or cooled, slowly or rapidly, it is subject to a vast number of different arrangements and internal combinations, which render it soft, hard, brittle, tough, ductile, elastic, malleable, etc., according to its chemical composition and heat treatment. These phenomena have given rise to countless experiments, surmises, and discoveries, and have given us an enormous literature on the subject. The average student has no time to undertake the assimilation of this appalling mass of information and theory, much of which is so technical in its language as to bewilder anyone but a scientist or a steel specialist. The purpose of this article therefore, is to condense and sort out the main facts and substantiated truths for the benefit of the casual student and the practical man.

The varying chemical compositions, spoken of before, which were found to give widely differing qualities to the steel, show on examination certain molecular formations and arrangements that indicate the physical qualities of the metal. These different structures revealed by the microscope, give widely differing results from the effect of heat treatment, and the development of the two conditions, *chemical composition*

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*Instructor of Descriptive Geometry and Kinematics, Armour Institute of Technology.

and *heat treatment,* constitutes the history of steel.

There are four distinct eras in the history of tool steel:

(1) Carbon Steel—up to 1894.
(2) Self-hardening Steel—1894—1900.
(3) Experimental Era of High Speed Steel—1898—1905.
(4) High Speed Steel Era—1905 ——.

Carbon Tool Steel, as its name indicates, is chiefly an alloy of carbon (0.5 per cent. to 1.5 per cent.) and iron. Slight percentages of silicon, manganese, sulphur, and phosphorus are also found in the mixture, silicon and manganese being useful constituents, giving improved fusing and working qualities, together with increased ductility and resistance to shocks, provided the percentage is correct. Sulphur and phosphorus are impurities, and affect the toughness of the material, phosphorus tending to make the steel "cold short" (brittle), and sulphur making it "red short" (difficult to forge). These impurities must be kept at the lowest commercially possible amount.

Carbon Steel, by heating to a cherry red and then suddenly cooling (quenching), takes on a quality of extreme hardness, due to the presence of carbon, and in proportion to its amount. It has the quality of brittleness, which is lessened by adding limited amounts of silicon and manganese. Forging is difficult, and cannot be accomplished at a greater heat than cherry red. The hardened tool will not stand a heavy duty, because the frictional heat so generated will soften the tool. Thus the scope of the tool is limited. Its cutting speed on mild steel, taking off a light chip, is about 25 feet per minute under good conditions of hardening and homogeneity of structure, less than that under ordinary conditions.

Self-hardening steel was discovered thirty years before it came into anything like common use. Robert Mushet discovered it between 1860 and 1870. He found, by adding tungsten and chromium instead of manganese, that a tool was hard when slowly cooled after forging. That is, the tool required no extra heating to harden it after it had been forged. A carbon steel tool has no "edge" after forging, the slow cooling making it "annealed" (soft); but this new steel was already hard, and required only grinding. This steel was expensive, however, and for many years was only regarded as a fad. In the early 90's it was found that it would accomplish 45 per cent more work on hard forgings, etc., than the

carbon steel would do. But it was not adopted in many shops for cutting soft metals, until it was found that it would cut 90 per cent more than the carbon steel. This steel was really a high speed steel, but its proper heat treatment had not been discovered.

High Speed Tool Steel:

Up to 1898 it was universally supposed that steel was hopelessly ruined when heated to the "breaking down" point. This point is 1550° F. (cherry red), and tool steel was never allowed to be heated beyond that point either in forging or hardening. That year Messrs. Taylor and White were conducting experiments for the Bethlehem Steel Works, and accidentally discovered that there was a limit to the "breaking down" range, and that after passing 1700° F., tungsten steel regained the power of hardening, and further, that if it were heated to 2000° F. or up to 2200° F., it possessed the quality of "red hardness," that is, not losing its hardness when heated red.

This was a startling and revolutionary discovery, and upset all theory on the subject, opening an immense field for scientific research and commercial adaptation. Additional tungsten and chromium were used up to the point of saturation, and various substitutes were tried, such as molybdenum, vanadium, and nickel, and the result is the modern high speed steel.

The perfection of high speed steel has already brought about wonderful changes in machine design, in economy of production, in increased wages, and in the equipment of new shops. The production of a machine is vastly increased by using the new tools, and therefore it is not necessary to install as much machinery as was formerly the case. The tools, being capable of so much more work without injury, enable the workman to use his tools constantly without the trouble of rehardening and frequent sharpenings.

In order to compare the chemical composition of the various kinds of tool steel, a table is shown, which gives their usual percentages. This table is taken from Mr. Taylor's paper, "The Art of Cutting Metals," read before the American Society of Mechanical Engineers in 1907, probably the most valuable contribution on this subject yet published:

	W	Cr	C	Mn	V	Si	P	S	Speed per Min.
Jessop		.207	1.047	.189		.006	.017	.017	16 ft.
Mushet (1895)	5.441	.398	.15	1.578		1.044			25 ft.
Original Taylor-White (1901)	8.00	3.8	1.85	.30		.15	.025	.030	58 to 61 ft.
Modern High Speed Steel (1906)	18.91	5.47	.67	.11	.29	.043			99 ft.

The best makes of high speed steel now contain even greater percentages of tungsten, one to my knowledge containing about 23 per cent.

The Effect of the Different Constituents:

The above table shows that the progress of the steel development has raised and lowered and sometimes omitted entirely the different elements, and the reason for it is to be found in their effect on the quality of the metal. When this influence is studied it shows the necessity for careful heat treatment and a rigid insistence on the uniformity of the steels used.

What Makes Steel Hard?

Unquestionably it is the carbon content, as the hardness is found to vary directly with the amount of carbon. Upon heating an alloy of iron and carbon to certain temperatures, and then cooling slowly or rapidly, we find many differing molecular structures, which have certain characteristics—crystalline, fibrous, dark, light, uniform, irregular, or showing streaks, spots, polyhedra, and other differences in the section. Each of these structures is characteristic of a certain grade of steel, and in fact is an individual metal in itself. They have been classified by scientists and are given names, such as pearlite, carbide, martensite, troosite, austenite, cementite, sorbite, etc. The practical man has little interest in these, and it is contended by eminent iron-masters that the influence of microscopic examinations has been of very little importance in the development of high speed steel and its heat treatment.

Most of these metals are worthless for cutting tools. They may be flint hard, but have no resistance to abrasion or heating, or they may be brittle. It is the metal "carbide" that

is the useful one. In this alloy the carbon is thoroughly and uniformly united with the iron, its fracture is clean, and its hardness is intense. Unless this carbon can be kept suspended in solution, it softens on heating. Here is where ordinary tool steel fails. A comparatively low heat, caused by the friction of the chip, or by other means, will segregate the carbon, and change the structure to one of the useless metals, martensite or troosite. The addition of tungsten and chromium prevent this disintegration, and give the high speed steel the qualities which distinguish it.

Influence of Carbon:

Carbon is essentially a hardening agent. It increases the tensile strength and introduces a quality of brittleness. The brittleness is greatly increased in the supersaturated steels. It is found that steel is saturated (though there is contention over this) when 0.89 per cent of carbon is present. The greatest range of efficiency agreed on by all investigators, is 0.4 per cent to 0.9 per cent. Such steels are hard and comparatively tough. With more than this amount of carbon, the steels are not desirable, being difficult to forge, and the tools are inferior. Increasing the carbon renders the steel liable to break under unequal and intermittent cutting.

Influence of Chromium:

The next important step is to ascertain the influence of chromium in amounts from 1 to 6 per cent. Steels having a low percentage are very tough and perform excellent work on the softer varieties of cast iron and steel, but on harder materials the results are not as efficient. By increasing the chromium the steel becomes harder and has greater efficiency on hard materials. It is noted that with the increase of chromium there must be a decrease in carbon to obtain the best results.

Vanadium has been substituted for chromium and gave good results in the same way, but no better than the much cheaper chromium.

Influence of Tungsten:

Gledhill, of Armstrong & Whitworth (England), made experiments using tungsten up to 27 per cent. With from 9 to 16 per cent of tungsten, the nature of steel becomes very brittle, but its cutting efficiency is greatly increased. Beyond 16 per cent the results were no better. From 18 up to 27 per cent, the nature of the steel altered somewhat, and, instead of being brittle, became softer and tougher, and while such tools have the property of cutting very cleanly, they do not stand up well. My opinion on this point is that the correct amounts of carbon, silicon, and chromium offset this softness and compensate in the matter of cutting and wearing. The

addition of the small amount of vanadium, which is found in the Taylor-White formula, undoubtedly exercises a very beneficial effect here. Tungsten is the restraining agent that prevents the carbon from segregation under violent heat. Böhler states that tungsten lowers the fusion point of steel.

Influence of Molybdenum:

This element is rarer and therefore more expensive than tungsten, and its worth, as far as I can determine, is yet to be decided. As a rule it is an excellent ingredient in high speed steel, and possesses the qualities of tungsten in an intensified degree. A small percentage of molybdenum will accomplish the same results that four times that amount of tungsten will do. It has this peculiarity: Molybdenum steels do not require as high a temperature for hardening to obtain the greatest efficiency, and if tools are heated above 1832° F. (1000° C.), they are inferior and shorter lived. Combining molybdenum with tungsten gives good results in cutting efficiency, but probably the advantage (if any) is not enough to justify the increased cost.

Influence of Silicon:

Silicon in limited quantities increases the cutting efficiency of high-speed steels, sensibly increasing their hardness. By exceeding 3 per cent of silicon the cutting efficiency declines.

Other metals, nickel, vanadium, titanium, etc., have been experimented with, but the results do not seem to justify using them. Vanadium is found in the formulae of some good high speed steels in small amounts.

The Armstrong-Whitworth formula for 1905 is:

Carbon	0.55 per cent
Chromium	3.50 per cent
Tungsten	13.50 per cent

The Taylor-White formula for 1907 is:

Carbon	0.67 per cent
Chromium	5.47 per cent
Tungsten	18.91 per cent
Manganese	0.11 per cent
Vanadium	0.29 per cent
Silicon	0.043 per cent

As before stated, more tungsten is now used.

Summary of the Influence of the Elements:

Hardness, toughness, ductility, malleability, and resistance to the breaking-down effects of heat are the qualities sought for in tool steel, and these qualities are contributed by the above-named elements. Carbon gives hardness, chromium toughness, and tungsten hinders, and, under suitably chosen conditions, altogether prevents the changes that would result in softening the tool (i. e., segregating the carbon, etc.). Sili-

con assists in the hardening and toughening, as does also vanadium, and manganese assists in keeping the iron malleable.

The Value of Microscopical Tests:

"The ultimate test of a hardened steel is its working life as a tool, and while it may not be difficult to obtain the requisite hardness, it is difficult to obtain it with freedom from clinking and cracking, from brittleness or rottenness, and from warping. The hardness test alone is not sufficient, and it is to be regretted that the scientific literature does not take this more into account. Generally speaking, the literature of hardening bears very little relation to the actual practice of hardening. As a result, practical iron masters view with distrust researches on hardening, especially when founded on results of microscopical examination. As a matter of fact, no metallographical examination as yet (1907) published has been of the least service as a guide to the heat treatment of high speed steels, and but little to that of carbon steels. This does not condemn the microscope, but emphasizes the difficulties of interpretation, and also shows that many scientists are unfamiliar with the practical aspects."

This is the opinion of a Sheffield steel man (Mr. Longmuir) of distinction, and his words carry conviction on account of their directness and his last sentence. He is evidently fair. In view of the difficulties attending the interpretation of the minute classification of microscopical aspects, he suggests two broad generalizations to cover the whole field, to-wit:

(1) "Correctly hardened steel exhibits a fracture in which no definite or pronounced structure exists."

(2) "Spoiled steel is evidenced by the presence of definite and sharply defined structure."

Mr. Longmuir's experiments were made on commercially hardened steel, which proved by trial to be good or bad, and that is what the steel consumer desires to find out. On the other hand, we must admit that the practical man often takes the salesman's view of his products and practices, and considers them better than those of his competitors, while the genuine scientist takes facts as he finds them, and does not allow his opinions and interests to discard antagonistic evidence.

The Heat Treatment:

The chemical formulæ having been fairly established and discussed, let us examine into the importance and best methods of treating the steel. Upon the temperature to produce a particular condition in steel rests the final physical and mechanical properties of the material. An alloy of iron-carbon-chromium-tungsten, as forged, may have no commercial value,

yet a judicious heat treatment may cause a change in its elastic limit from 44,000 pounds to 120,000 pounds, and in its ductility from 8 or 10 per cent to 30 or 35 per cent. Wrong heat treatment has caused many a manufacturer to condemn high speed steel as useless because of its brittleness. There is absolutely no ground for this if directions are followed. "The treatment is as important as the composition of the steel," is the statement of Fred M. Osborn (Samuel Osborn & Co., Ltd., makers of mushet steel). F. W. Taylor, the discoverer of "red hardness" and how to obtain it, says much the same, to-wit: "I find that different reliable steels are all good, if the heat treatment is good, and that the one method given is suitable for all good grades, and will bring about the same conditions."

As an instance of the necessity for careful treatment of the steel, Brayshaw maintains that a difference of one degree Centigrade in heating steels makes a difference in hardening, and that five degrees Centigrade (nine degrees Fahr.) constitutes the difference between good and bad hardening. In view of the high heat required for hardening high speed steel (2,300° F.) this scarcely seems reasonable. Average practice probably does not do better than to keep the variation down to less than 10° C. (18° Fahr.). It is doubtful whether the human eye can keep it closer to the standard than this. My opinion is that a variation of 100° F. is not serious and that any heat between 2,200° F. and 2,300° F. will give first class results.

The three operations in the heat treatment of tool steel, whether high speed or ordinary, are forging, hardening and tempering. Before giving the details of the processes, their general nature will be defined, and no attention will be paid to any but high speed steels.

Forging:

The shaping of the tool under the hammer or press must be done at a yellow heat, 1,900° F., and when it falls to 1,750° F. (bright red), it should be reheated before further hammering. Any forging done at a lower heat will result in cracks and splintering that will ruin the tool.

Hardening:

Tools and implements are too soft as they come from the forge. Hardening is accomplished by heating to temperatures which vary in accordance with the carbon content, and then cooling suddenly by immersion in a bath of air, water, oil, lead, etc. Slow cooling will also harden high speed steels.

Tempering:

When cooled suddenly, steel is sometimes too brittle for most cutting purposes, and this quality of brittleness is removed or modified by reheating to temperatures varying between 400° F. and 600° F. The higher it is reheated within

these temperatures the softer it becomes, and this reheating for toughening and partially softening tools is called "tempering."

Difficulties in Hardening:

(a) Each tool, depending on its chemical composition, has a peculiar temperature at which a radical change in the condition of its carbon takes place. This temperature is called variously the "critical point," "refining point," and "point of recalescence." In order to obtain the best results the steel must be heated uniformly to a temperature slightly above this point. Otherwise it fails to harden on quenching. If the heating is carried much above the critical point the grain is coarser and there is increased weakness and brittleness after quenching.

(b) The lack of uniformity in heating causes internal strains, and causes cracks to set up on cooling.

(c) It is difficult to cool properly. Uneven or irregular cooling produces severe internal strains called water cracks.

From the foregoing it will be seen that it takes skill and judgment in treatment to bring about the necessary combination of toughness and hardness.

The Taylor-White Process:

Inasmuch as this is the original process, and there is little to choose between the various good methods of hardening, we shall describe only this one for general purposes. The description is condensed from Mr. Taylor's paper before mentioned.

After the tool has been forged, the entire nose should be slowly and uniformly preheated to a bright cherry red, allowing plenty of time, so that the heat may penetrate thoroughly to the center. From the bright cherry red up to the melting point the tool should be heated as rapidly as possible in an intensely hot fire, until the nose begins to soften. No harm is done if the points are slightly fused. At this point a thorough heating is necessary, and time should be given for the whole nose of the tool to arrive at a uniform temperature.

No apparatus should be used for preventing portions of the tool from heating. The whole end of the tool should be given a uniformly high temperature. (Note: This last statement, if accepted, would entirely condemn a method called the shield treatment. Lack of space prevents a discussion of this and other special treatments.) If the fire gives a sufficiently intense heat, a tool two inches square and three inches long can be properly heated in three minutes from a bright cherry to the required high heat. Smaller tools require from three-fourths of a minute up. In this treatment the tool should be large enough in forging to allow one-sixteenth to one-eighth of an inch for grinding, because of the oxide scale that is formed in heating.

It has been found than between 1,550° F. and 1,700° F. there is a bad condition in the steel structure, and that steels heated in that range and then cooled are ruined. This is called the "breaking down" temperature. Beyond this point we find the proper hardening conditions. To get the best and most uniform results with high speed tools after their high heat has been given them, they must be cooled rapidly until they are below the breaking down point. From there down the quality is little affected either by slow or rapid cooling.

The best method of cooling below the breaking down point is to plunge in a bath of red molten lead under 1,550° F. Then plunge into a lead bath at 1,150° F. This latter bath must be kept at a constant temperature, because it is also used for reheating tools for second treatment. It must therefore be a large body, say 3,000 pounds. Too small a bath will have its temperature affected by the quenching operation. The temperature must not be allowed to be even slightly raised at any time during cooling down to 1,240° F., or the tool will be ruined. Below that point it is immaterial.

Recapitulation:

(a) Heat slowly to 1,500° F.
(b) Heat rapidly to 2,200° F. (near fusion).
(c) Cool rapidly to below 1,550° F.
(d) Cool rapidly or slowly to air.

Second, or Low Heat Treatment:

This consists in reheating the tool to 700-1,240° F. The best practice is to place the tool in the lead bath mentioned for a second quenching, and when heated, to cool it with air blast or slowly. It should be preheated before plunging into the lead bath to avoid fire cracks. 1,150° F. is a good temperature for this bath, as it is not likely to be raised above the critical temperature of 1,240° F. The good effect of the second treatment is that it increases the quality of "red hardness."

The Barium Chloride Process:

For hardening fine tools that must retain their cutting edge and size, as, for instance, taps and milling cutters, there is no process, in my opinion, equal to the "barium bath." Fine tools cannot be made as well, if they are made oversized and then ground down. But if a scale of oxide is formed on the tool, it has to be ground down. Packing in muffles and other devices, such as the electrical method, help, but do not entirely overcome the difficulty, and some are troublesome. The lead bath has been tried, but does not answer for high speed tools, although it is reasonably satisfactory for carbon steels.

Lead can be raised to the required temperature, but a scum of lead oxide obscures the appearance of the bath, and tools will float unless held down. Moreover, the tool oxidizes

in passing from the heating bath to the quenching bath, and in delicate tools this is sufficient to ruin them.

The bath of barium chloride was first used in Germany to replace the lead bath. It is now used in this country by many firms, and is found to be satisfactory. A crucible large enough to hold a barrel or so of barium chloride is placed over a foundation of fire brick with plenty of holes for the circulation of flames. The gas has a rotary motion about the crucible and heats it from all sides. Above the crucible is a hood to draw off the fumes, etc. The barium chloride salt is placed in the crucible and raised to 2,200° F. This is easily gauged and maintained by connecting the bath with a pyrometer, of which there are several inexpensive makes. The disagreeable chloride fumes can be kept at a minimum by adding a handful of sodium carbonate (soda ash). Care must be taken to avoid adding too much, as it renders it impossible to raise the solution to the desired temperature.

When the bath is heated to 2,200° F. (some steel men urge 2,300° F. as the best temperature), which is a white heat, place the tool in the bath, and let it soak until it is raised to the temperature of the bath. Let the tool remain for a few minutes until it is thoroughly heated, for one of the essentials to good hardening is thorough heating. In the case of taps, where the cutting edges are required to be very hard, with a relatively soft body, the tool is not left long enough to heat anything but the edges to the highest point. If large tools are to be hardened, they should be preheated to a low red in a muffle, so as to prevent cooling the barium bath on immersion. The addition of a large piece of cold metal lowers the temperature of the bath considerably.

Quenching:

Air quenching is perfect for this process because the coating of barium chloride on the tool prevents oxidation upon removal from the bath. An air blast is expensive, costing 60 cents an hour to maintain a 60-pound pressure on a four-inch blower. When tools are cooled by air they are laid in a wooden trough and the blast from the blower passes over them. An oil bath is more economical, as there is practically no loss of oil, and the first cost is about all there is of it. After the tool has been heated thoroughly and uniformly, and is left a few minutes (never over ten minutes) in the barium bath so as to unify the metal, the tool is removed and immediately plunged in the air or oil bath. Tools with delicate edges require tempering after this. The tanks with their proper heating arrangements and appliances for handling the work may be purchased outright, and it is hardly necessary to describe them in this article.

After the coating of barium scale has been brushed off the tool, it is found to be of its original size, and of very much the same appearance as before heating. Under ordinary processes of hardening and tempering the tool takes on a blue or brown color, according to the method. In this process, however, the color is unchanged, because there is no chemical action on the steel, the coating of barium chloride acting as a shield against any oxidation. Many workmen are amazed at the appearance of the tool and refuse to believe that it has been hardened at all.

Pyrometers:

Many tool shops still adhere to the most natural means of detecting the hardening temperature, the eye. Owing to the accuracy with which the final temperature and the cooling points must be gauged, and the strain on the man employed for that work, it is both economical and merciful to use an accurate recording instrument for the work. A number of good instruments have been placed on the market. They are not expensive, and give accurate readings. For experimental purposes they are invaluable.

Summary:

High speed steel must not be regarded as an extraordinarily hard steel. The old style of carbon steel was fully as hard, but the new steel possesses the property of holding its hardness under duty that would immediately ruin a carbon steel tool. For working on armor plate, plow shares, hard steel forgings and similar work nothing but tools of high speed steel are now used. The increased duty which the high speed steel is capable of sustaining, has revolutionized the design of lathes, planers, drill presses, etc., because the old style machines were built neither heavy nor fast enough to do the tools justice. Grinding and re-hardening have been reduced to a minimum because the tools "stand up" under the work.

Summary of Hardening:

The rules for heating ordinary tools, leaving fine tools out of the question, may be summed up in the following:

(1) Heat uniformly, heat thoroughly, cool uniformly and pass through the breaking down quickly in both directions.

(2) Use three furnaces or baths for the heating, and quench in air or oil.

The following table will be found simple and useful in hardening high speed steel:

Temp.	Color	Condition of Steel	Heating	Cooling	Forging
2300	White	Best hardening temperature.	Allow tool to remain at the high point to be uniformly heated.	Quench quickly in air blast or oil bath.	
2200 2100 2000 1900 1800	Yellow	Best forging temperature.			Forge at this temperature. Upon falling to 1700°, reheat before doing any more work.
1700 1600 1550	Bright Red Cherry	Breaking down temperature. Heating to this point and cooling ruins tools.	From 1550° to 2300° the heating must be fast in an intense fire.	Cool very quickly through breaking down range.	
1400			Heating may be slow to 1550°.	Cool slowly from here down. Internal strains lessened, equivalent to annealing.	Do not harden right after forging. Give fibres a chance to accomodate themselves to new conditions by cooling slowly.
1300 1200 1100	Low red	Point of recalescence in high speed steels. Varies considerably. Carbon steels have lower critical point.	Tool should be preheated to a red heat.		
Atmosphere					

The Hardening of High Speed Steel.

THE CONSTRUCTION AND USE OF LOGARITHMICALLY RULED CO-ORDINATES; GENERAL DIAGRAMATIC SOLUTION OF GAS PROBLEMS.

BY J. M. SPITZGLASS.*

It is the object of this article to illustrate the use of logarithmically ruled paper for simplifying the parabola and higher degree curves, and the use of either the reciprocal or a multiplication diagram for simplifying the hyperbola, especially for the pressure-volume curves of a gas.

Logarithmically Ruled Paper:

Fig. 1 illustrates the construction of this type of co-ordinate paper. A four-place table of logarithms is used, and a base of ten inches on the diagram is taken for unity of logarithm, each inch on the axis representing a unit in the first decimal place of the logarithm. The second and following places of the logarithm are laid off on the corresponding decimal divisions of the inch.

Beginning with the origin of rectangular co-ordinates, lay off to the given scale on both the vertical and horizontal axes, logarithms of numbers in natural order. Mark at each point the number corresponding to the logarithm and also the distance from the origin in inches. The first scale is denoted by A and the second by B, so that at any point the logarithm of A equals B. The origin, representing the zero value of logarithm on scale B, will therefore correspond to the unit of the numbers on scale A, since the logarithm of unity is zero; and the end of the ten inch base representing the unit value of logarithm will necessarily correspond to ten units of the numbers, or to a number ten times larger than the one at the origin.

Now draw a straight line from the origin having a slope of one to two with the horizontal, or axis of abscissas. It will be noticed that the vertical distance of any point on the line from the origin is equal to one-half of the horizontal distance of that point from the origin, while the number corresponding to the first distance is equal to the square root of the number corresponding to the second distance; in other words, the number corresponding to the abscissa of any point will be the square of the number corresponding to the ordinate of that point.

The algebraic explanation of this fact is as follows: A straight line represents a linear equation of the general form

$$y = cx,$$

where

y is the ordinate of any point in the line,
x is the abscissa of the same point, and

*Class 1909. With Armour Glue Works.

c is a coefficient determining the slope of the line, or the ratio of y to x.

In the case of the diagram given, if x and y are the co-ordinates of any point on the line, as referred to the axes calibrated in inches, or to the logarithmic scale B, then

$$y = \tfrac{1}{2}x \qquad (1)$$

Let us now consider the co-ordinates of the same point on

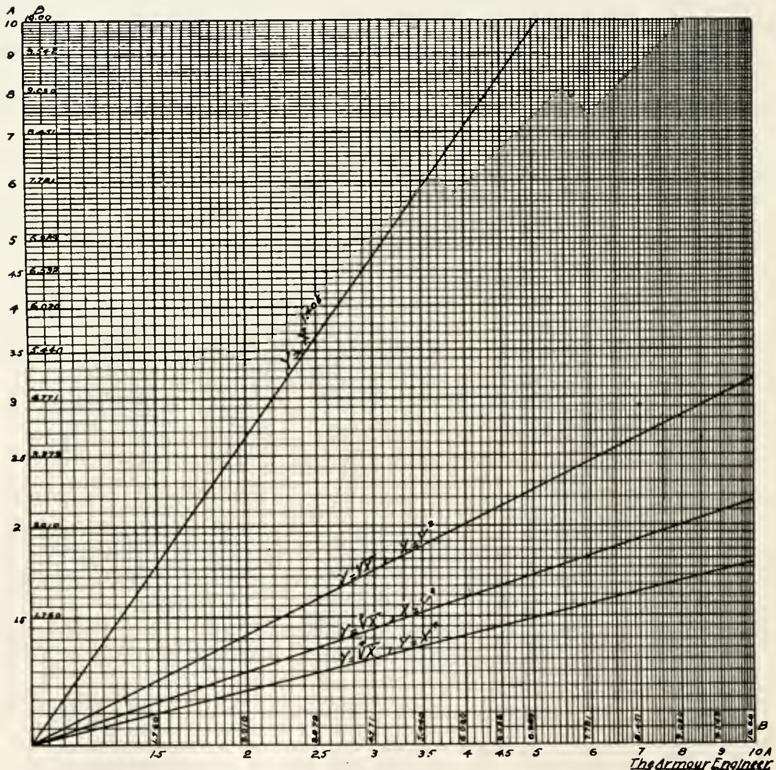


FIG. 1. LOGARITHMIC SCALE CO-ORDINATES—10-INCH BASE.

this line referred to the numerical scale A, and call the co-ordinates x_1 and y_1 respectively. For any point,

$$\log x_1 = x$$

and $$\log y_1 = y.$$

Thus equation (1) can be written

$$\log y_1 = \tfrac{1}{2} \log x_1$$
$$\log y_1 = \log x_1^{\frac{1}{2}}$$

Therefore

$$y_1 = \sqrt{x_1}$$

and $$y_1^2 = x_1.$$

In the same manner a line sloping one to three with the horizontal will give the relation of numerical co-ordinates

$$\log y = \tfrac{1}{3} \log x \; .$$

Therefore

$$y = \sqrt[3]{x}$$

and $$y^3 = x.$$

(The subscript 1 is omitted in this equation.) A line with a slope of one to four will give the relation of the fourth power and fourth root. In general, the slope of the line will represent the exponent of the power to which the abscissa of a point in the line must be raised in order to get the ordinate of the same point. The diagram therefore affords a convenient solution for any fractional power or root. As an example, one line is shown in Fig. 1 having a slope of 1.405 to one with the horizontal. The equation of the line is

$$y = x^{1.405}.$$

(1.405 is the value of the exponent "n" in the equation for the adiabatic compression of air,

$$pv^n = p_1v_1^n,$$

and the line can be used conveniently for the solution of that equation).

Fig. 2 shows a convenient form of logarithmic co-ordinates for the solution of powers and roots. The y-axis on this diagram is subdivided to a ten-inch base, while the x-axis is subdivided to a five-inch base. In this case a slope of 45° solves the square and square root of the given numbers; a slope of two to three solves the cube and cube root; one to two, the fourth power and fourth root, and so on.

The application of the diagram for any particular power is not limited to the space covered by the first section of the line. For example, the fourth power line on the diagram intersects the right end at a height of five inches, the corresponding

numerical ordinate being the fourth root of 100, or 3.16. Suppose we continue the line in the same direction until its length is doubled, and we subdivide the space to the right to the same logarithmic scale. From similar triangles, the line will reach a height of ten inches, corresponding to the numerical ordinate of ten, and a horizontal length of 20 inches, corresponding to a numerical abscissa of 100 times 100, or 10,000. Imagine the proposed addition to be superimposed on the present diagram. The subdivisions would be the same for the y axis of both

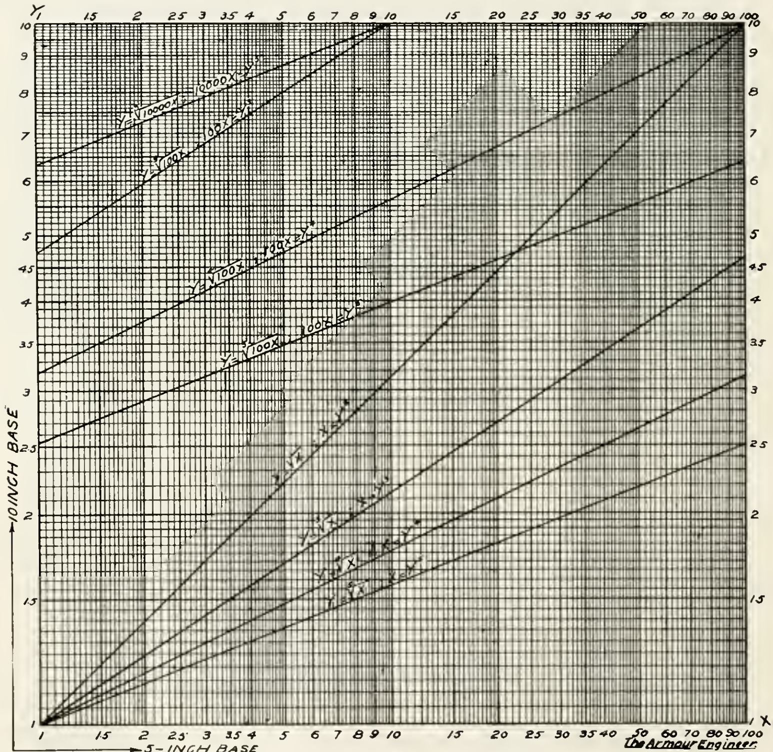


FIG. 2. LOGARITHMIC SCALE CO-ORDINATES—SOLUTION OF POWERS AND ROOTS.

diagrams, and in the ratio of 1 to 100 for the x axis; the additional part of the line would be moved ten inches in a direction parallel to the x axis. It follows that this part of the line can be drawn directly on the present diagram. It starts on the left side of the diagram at the same height at which the first part ends on the right side, and the two are parallel to each other. The change in the abscissa, which

amounts to shifting the decimal point two places to the right, is taken care of by the equation marked on the line,

$$y = \sqrt[4]{(100x)}$$

and $$100\,x = y^4.$$

The third and fifth power lines were treated in the same manner; the latter required a third addition to cover the range, this being equivalent to a third subdivision, or a new factor of 100 to the abscissa. Its equation is therefore marked

$$y = \sqrt[5]{(10{,}000x)}$$

and $$10{,}000x = y^5.$$

The principle can be extended to include any one of the standard functions involving higher degrees. For example, in Fig. 3, if the second power line in the logarithmic diagram be moved parallel to itself until the intercept cuts the x axis at a numerical abscissa of 0.7854, then the abscissa of any point in the line will be equal to the numerical value of the area of a circle whose diameter is the ordinate of the same point, because the log of 0.7854 is a constant quantity added to the abscissa of each point in the line and does not change its slope. A line parallel to these with the intercept of the x axis at $\frac{1}{64.4}$ will solve the equation

$$h = \frac{v^2}{2g},$$

v being the velocity of a freely falling body, or of a moving fluid, h the height, or head equivalent to the velocity, and g the acceleration of gravity, 32.2 feet per second, per second.

Fig. 3 shows a collection of similar lines for the solution of the second, third, and fourth power functions. The lines are repeated to cover the entire range of the diagram, each part being marked by the proper equation. The use of this diagram only locates the decimal point for the first part of each line, the rest being determined by inspection.

Diagramatic Solution of Gas Problems:

The recent development of gas engineering necessitates frequent calculations in problems involving the practical use of the various gases. The pressure-volume curve of a perfect

gas, being an equilateral hyperbola, is used extensively for comparison with the expansion lines of indicator cards. For calculating purposes, however, the hyperbola should be reduced to a straight line giving the relation of the two factors to each other, and to the third important factor, the temperature.

The reduction can be done in a number of ways. One of them is to supplement the volume ordinate by its reciprocal,

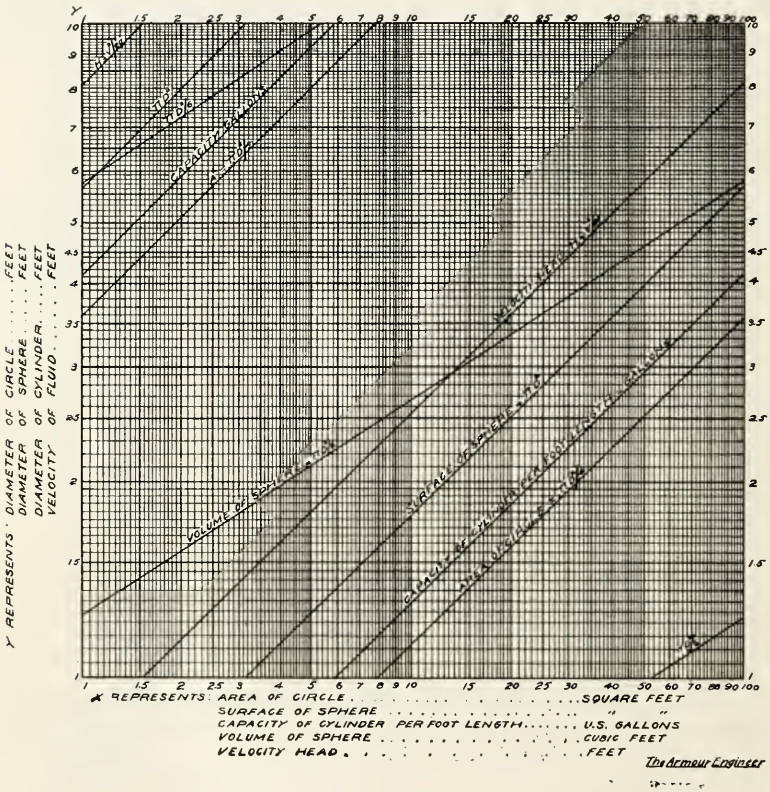


Fig. 3. Diagramatic Solution of Standard Functions.

$\frac{1}{v}$, or unity divided by the volume. From the equation representing Boyle's law for a perfect gas at a constant temperature,

$$pv = c,$$

where p is the pressure above vacuum, v is the volume of the gas, and c is the numerical value of the product, which is a constant quantity for any one gas at a constant temperature. Hence we have

$$p = \frac{c}{v} = c \times \frac{1}{v},$$

which is the equation of a straight line.

Fortunately, the reciprocal of the volume if taken in proper units, will show the density or weight of the substance, so that we may have on the same chart the relation of all four of the variables specifying the nature of a gas—namely, pressure, volume, density and temperature.

Consider now the gas product "pv" or "c" as a single quantity varying wholly according to a certain law. The numerical value of this product will be determined, first, by the nature of the gas; second, by the weight, or amount of matter in the same; and third, by the temperature. The nature of the gas introduces a factor, which is constant for the same kind of gas; this factor is usually noted by R. The weight of the gas will be another factor, which will be represented by W; and according to Charles' law, the volume of a gas varies in direct proportion with the absolute temperature (Fahrenheit degrees plus 460), when the pressure is constant; hence, the volume times the pressure varies in the same proportion, and since any local change between the factors pressure and volume has nothing to do with the law of variation of the whole product, therefore this product will always vary in direct proportion with the absolute temperature, and we may substitute a third factor denoted by T.

Expressed algebraically we have

$$pv = c = RWT,$$

W being the weight of the gas in pounds,
T the absolute temperature, and
R a coefficient depending upon the set of units used in the equation.

Since R is a constant quantity for the same kind of gas, its numerical value can be determined from the solution of one known case. For example, the volume of one pound of air at atmospheric pressure (14.7 pounds per square inch) and zero temperature (460° F. absolute) is 11.57 cubic feet.

$$pv = RWT$$
$$14.7 \times 11.57 = R \times 1 \times 460$$

$$R = 14.7 \times \frac{11.57}{460} = 0.371.$$

In the same manner for hydrogen, R equals 5.33, and for oxygen R equals 0.336. For illuminating gas (specific gravity 0.58, air = 1), R equals 0.64.

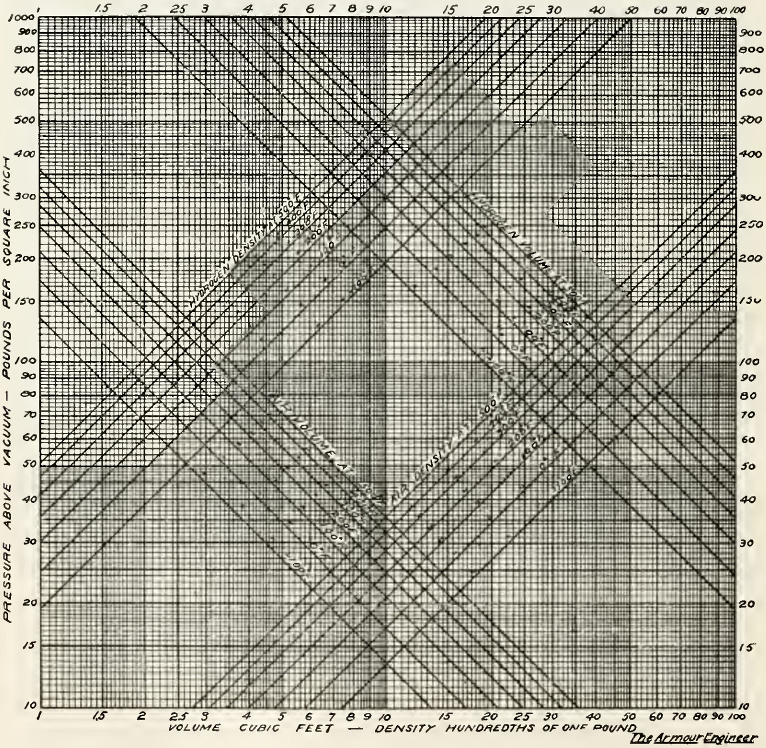


FIG. 4. SPECIFIC VOLUME AND DENSITY OF AIR AND HYDROGEN AT VARIOUS TEMPERATURES.

Returning to the curves (See Fig. 4), let the ordinate or vertical scale of logarithmic co-ordinates represent the pressure of a gas in pounds per square inch. Let the abscissa or horizontal scale read volumes in cubic feet, and densities in hundredths of a pound to the same scale.

For any value of the gas product c,

$$p = c \times \frac{1}{v}$$

and $$\log p = \log c + \log \frac{1}{v} = \log c - \log v.$$

As seen from the equation, $\log \frac{1}{v}$ and $\log v$ have the same numerical value, one being positive and the other negative with relation to the pressure p, and therefore, if we make c constant, which is done by taking the condition of a given constant temperature, we have $\log \frac{1}{v}$ and $\log v$ both varying in the same proportion with $\log p$, one in the positive direction —diagramatically from left to right, and the other in the negative direction—from right to left; and from simple proportionality, the slope in both cases will be 45° from the horizontal.

When v is the volume of one pound of a gas, then $\frac{1}{v}$ is the density of the same gas, and the product c equals RT. For atmospheric air at zero degrees F.,

$$RT = 0.371 \times 460 = 171.$$

Beginning at zero degrees Fahrenheit,

Let $v = 10$ cubic feet

then $\frac{1}{v} = \frac{1}{10} = 10$ hundredths of a pound

and $$p = c \times \frac{1}{v} = 171 \times \frac{1}{10} = 17.1.$$

It follows that at an ordinate of 17.1 the volume and the density of air for zero temperature have a common abscissa of 10. Since the slope is known to be 45°, the two lines are

determined by the location of this point, which is necessarily at their intersection.

For any other temperature, say 100° Fahrenheit, the point of intersection is located in the same manner. The abscissa will be 10 again, since v and $\frac{1}{v}$ must have the same numerical value on the diagram. The ordinate

$$p = c \times \frac{1}{v} = RT \times \frac{1}{v}$$

$$= 0.371 \times (460 + 100) = 20.78$$

Fig. 4 shows one series of lines for atmospheric air and one for hydrogen. By interpolation between the given lines the specific volume and density corresponding to any given pressure and temperature can be read from the horizontal scale directly.

The problems usually occurring in practice, however, are not concerned so much with the specific volume as with the change in volume of a given amount of gas. A number of cubic feet are delivered at a certain pressure and temperature, and it is desired to know what the equivalent volume is at a different pressure and a different temperature. A diagram for the general solution of gas problems in both the French and English systems of units is given in Fig. 5. This diagram can be used for any kind of a gas, including the specific volume and density of the same as one special case.

Essentially Fig. 5 represents a multiplication diagram. A number of oblique lines are drawn at regular intervals on a sheet of rectangular co-ordinate paper. Each line is marked by a number in proportion to the slope of the angle it makes with the horizontal. The co-ordinate scales are subdivided in such a manner that the vertical ordinate of a point in any of the oblique lines shows the product of two factors, one being the abscissa of the same point, and the other the number marked on the oblique line.

Now, the fact that our gas product c in any system of units has two sets of factors, one pv and the other RWT, enables us to solve any of the various gas problems by means of this simple multiplication diagram. Furthermore, the diagramatic solution will greatly emphasize and make clear the changes required by the conditions of the problem.

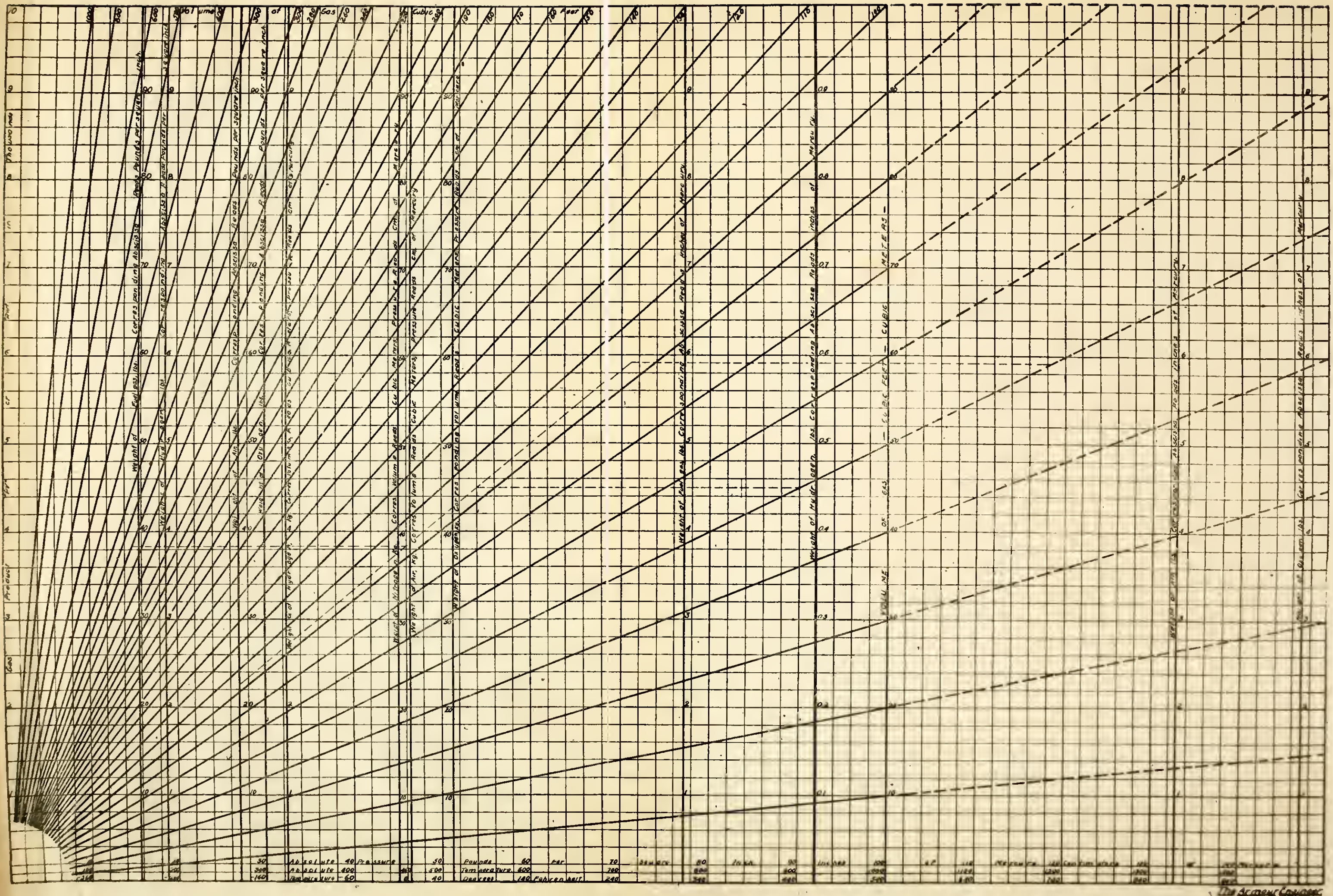
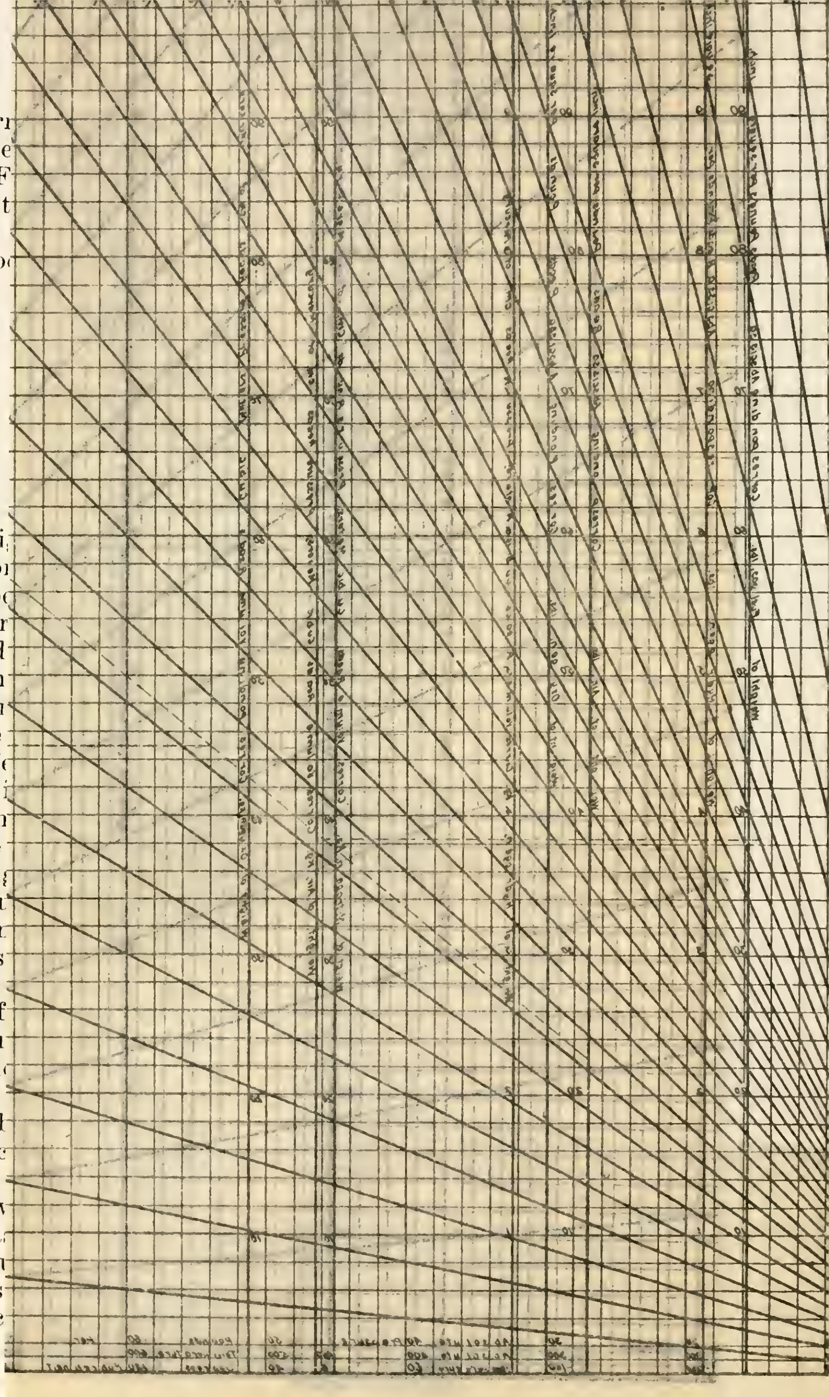


Fig. 5. Universal Diagram for the Solution of Gas Problems.



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The horizontal scale of the diagram is designated to read either the absolute temperature, or the pressure of the gas in any system of units indicated by a given problem. The oblique lines will substitute the proper volume factor for the pressure, and the corresponding weight factor for the temperature, while the vertical scale will always be the common product. The weight factor on the oblique lines will necessarily include the coefficient R, which is reduced to unity by placing the scale for the weight readings at a distance from the origin in proportion to the reciprocal of R, $\frac{1}{R}$, making the equation

$$pv = WT,$$

and at the proper distance a line is drawn for the given gas and the given system of units to read the weight directly.

The method of carrying a problem through the diagram is very simple. One set of factors given, either the pressure and the volume, or the weight and the temperature, for a given system of units, will determine the value of the product for that system, or rather, the height of the vertical ordinate (which is all that is desired), by the intersection of the oblique line with the proper abscissa. This height once determined will not change unless a change is produced in the temperature. The variation of pressure and volume will not affect the ordinate at all; and therefore if the pressure is changed to a known value the corresponding volume will be found on the oblique line intersecting the new pressure at the same vertical height; and vice versa, if the volume is changed, the corresponding pressure will be found on the horizontal scale at the intersection of the new volume line with the same vertical ordinate. When the temperature changes, the gas product will necessarily change in the same proportion. And since the weight of the gas always remains constant for the same amount, therefore, the new vertical ordinate will be located by following the weight line to the intersection with the new temperature.

The following examples will illustrate the practical use of the diagram:

Example 1:

A cylinder of 50 cubic feet capacity is filled with compressed air at 90 pounds per square inch absolute pressure. The temperature being 80° F., required;

(a) The total weight of air in pounds.
(b) The pressure if the air is heated to 250° F.
(c) The volume of the air at atmospheric pressure and zero degrees F. temperature.

The intersection of the given set of factors, the 90-pound pressure abscissa with the oblique line marked 50, locates at once the gas product or the vertical ordinate for the given amount of gas at the given temperature (80° F.). Follow horizontally to that temperature, which is one factor of the second set; an oblique line through this point and the origin will be the other factor of the set, and will necessarily represent the weight of the air. This line intersecting the air scale reads 22.5 pounds, which is the required weight.

Now follow the same weight line up to 250° F., where the gas product at that temperature for the above weight is located. Go horizontally to the 50-cubic-feet oblique line, and read the corresponding pressure on the horizontal scale, 118.5 pounds per square inch, which is the pressure resulting from the rise in temperature.

Pass back horizontally to the weight line, and follow it down to zero degrees F. (Remember that any change in temperature follows along the weight line only.) The vertical ordinate is located at this temperature. Follow horizontally to the abscissa for 14.7 pounds per square inch, and the oblique line passing through the intersection reads 260 cubic feet, which is the proper volume at atmospheric pressure and zero temperature. The solution of this example is indicated by dotted lines on the diagram.

Example 2:

Given the following data of a gas engine test:

Fuel consumed per hour..............750 cubic feet
Temperature of gas ....85° F.
Pressure at gas meter.........29.6 inches of mercury
Air used per hour ....8,560 cubic feet
Temperature of air ....85° F.
Barometric pressure .... 29.5 inches of mercury
Data from indicator card (See Fig. 6).

Atmospheric pressure at 90 per cent of total volume (including clearance space).

95 pounds (absolute) compression at 18 per cent of total volume.

Maximum pressure, 335 prounds at 20 per cent of total volume.

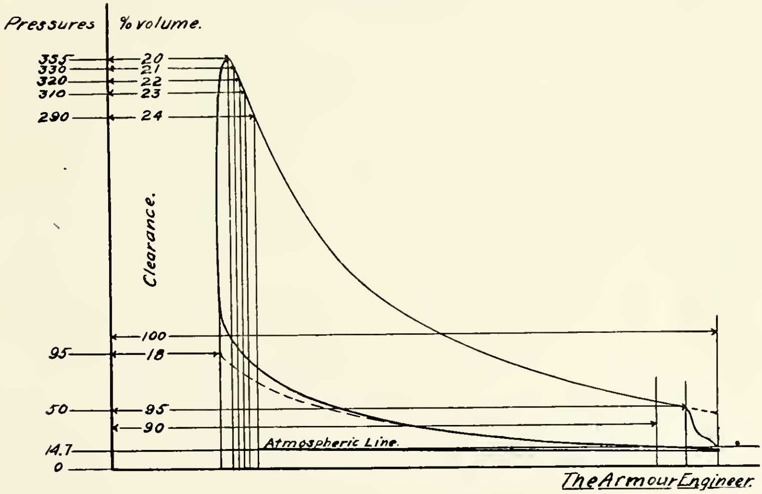
Pressure drops to 330 pounds at 21 per cent of total volume, 320 pounds at 22 per cent, 310 pounds at 23 per cent, and 290 pounds at 24 per cent of total volume.

Exhaust opens at 95 per cent of total volume, and 50 pounds absolute pressure.

Required:

(a) Weight of gas consumed per hour.
(b) Volume of gas reduced to standard conditions (62° F. and 30 inches of mercury).
(c) Total weight of air used for combustion.
(d) Temperature of mixture at compression.
(e) Maximum temperature.
(f) Temperature of mixture at opening of the exhaust valve.

Solution given by the diagram:



(a) Weight of gas consumed per hour. Take the intersection of the abscissa 29.6 with the oblique line 75 (using 75 instead of 750 cubic feet for convenience). Follow horizontally to 85° F., and locate the oblique line passing through this point and the origin. This line, intersecting the weight-of-fuel-gas line corresponding to inches of mercury, reads 3.16, which is the weight of 75 cubic feet. The total weight is therefore 31.6 pounds.

(b) Volume of gas reduced to standard conditions. Pass down along the oblique weight line located for the solution of (a) to its intersection with the 62° F. abscissa. Follow horizontally to 30 inches of mercury. The oblique line passing through this point reads the volume 718 cubic feet (71.8 on the diagram).

(c) Total weight of air used for combustion. The intersection of the 85.60 oblique line (the decimal point being shifted two places) with the 29.5 pressure abscissa determines

the vertical ordinate of this product. Follow horizontally to 85° F. The oblique line through this point intersecting the weight-of-air line for inches of mercury reads 6.16 pounds for 85.6 cubic feet. The required weight is therefore 616 pounds.

(d) Temperature of mixture at compression. The oblique line will now read per cent of total volume. As to the original temperature of the charge mixed with the hot exhaust gases of the clearance space, it will be safe to assume 140° F. If desired, the exact temperature can be used for each part separately, the weight lines being determined and added to make the total. The assumption of a common temperature, 140° F., however, is accurate enough for all practical purposes.

From the data of the indicator card the charge was at atmospheric pressure when at a volume of 90 per cent of the total volume. Take the intersection of the oblique line 90 with the 14.7-pound pressure abscissa. Go horizontally to 140° F. and locate the oblique line passing through the point. This line is not exactly the weight line of the given mixture, but it is the line of constant weight determined by the pressure, volume, and temperature; and the gas product, or vertical ordinate must vary along this line with the change in temperature. At compression the pressure and per cent of volume are given (95 pounds absolute pressure and 18 per cent of total volume). Take the vertical ordinate determined by the intersection of the oblique line 18 with the 95-pound pressure abscissa. Follow horizontally to the intersection with the line of constant weight, and read the abscissa, 320° F., or 780° absolute, which is the temperature at compression.

(e) Maximum temperature of mixture. This temperature does not necessarily occur at the peak of the pressure, since the product, pressure times volume, upon which the temperature depends, may have a maximum much later if the per cent of volume increases rapidly. In the data of the indicator card, we have given several pressures corresponding to equal increments of volume. Taking the intersection of each pair in order, we find that the highest vertical ordinate is given by the 23 per cent volume oblique line with the 310-pound pressure abscissa (using 31 on the diagram). Follow the height of this ordinate to the intersection with the oblique line of constant weight determined at the start, and read the absolute temperature on the horizontal scale, 3200° (320 on the diagram) or 2740° F.

(f) Temperature of mixture at opening of the exhaust valve. Take the intersection of the 95 per cent volume line with the 50-pound pressure line (use 5-pound abscissa on the diagram in order to have the intersection within the height of the constant weight line). Follow horizontally to the constant

weight line, and read the corresponding absolute temperature 2150°, or 1690° F.

Example 3:

Illuminating (fuel) gas is delivered through a six-inch high pressure main over a distance of 30 miles. The pressure in the main is 30 pounds gauge (41.7 pounds absolute), leaving the compressor at the starting point at a temperature of 160° F., and 15 pounds gauge (29.7 absolute) at the other end of the main at a temperature of 50° F. Required:

(a) How many pounds of the drop in pressure are used up in friction and delivery of the gas, if the total condensation in the line amounts to 5 pounds of liquid per thousand cubic feet of gas delivered at standard conditions (62° F. and 30 inches of mercury)?

(b) What will be the final pressure at the temperature of 50° F. if the gas leaves the compressor at 20 pounds gauge and a temperature of 140° F.?

Use 100 cubic feet as a unit for convenience. Take the intersection of the volume 100 line with the 30-inch pressure abscissa. Pass horizontally to 62° F., and locate the oblique line passing through this point and the origin. This line intersects the weight-of-fuel-gas line for inches of mercury at 4.44 pounds pressure. Now pass to the pound per square inch system and locate the vertical ordinate for the condition of the gas leaving the compressor by the intersection of the 160° F. abscissa with an oblique line passing through 4.44 pounds on the weight-of-fuel-gas line for pounds per square inch pressure. Pass horizontally to the given pressure 44.7 pounds abscissa. An oblique line through this point indicates the corresponding volume, 41.0 cubic feet. The condition at the other end of the line for the same volume is a loss in weight of 0.5 pounds, or a final weight of 3.94 pounds. The vertical ordinate is now determined by the intersection of an oblique line passing through 3.94 pounds on the weight-of-fuel-gas line, and the 50° F. abscissa. Follow the ordinate to the intersection with the 41 cubic feet volume line and read the corresponding pressure on the abscissa, 32.9 pounds absolute or 18.2 pounds gauge. The loss in pressure due to friction and delivery is therefore 18.2 — 15 (reading of gauge at the end of the line), or 3.2 pounds per square inch.

(b) The same 4.44-pound oblique line intersecting the 140° F. abscissa determines the vertical ordinate for the proposed condition of the gas as it leaves the compressor at 20 pounds gauge pressure. Follow this ordinate to the 34.7 pressure abscissa (20 pounds gauge), and read the equivalent volume as 52 cubic feet. The intersection of 3.94-pounds oblique line and the 50° F. abscissa will give the vertical ordinate at

the other end of the line. Pass horizontally to the 52 cubic feet volume line and read the corresponding absolute pressure, 25.6 pounds or 10.9 pounds gauge. Subtracting 3.2 for delivery, the final pressure will be 10.9 — 3.2 or 7.7 pounds per square inch gauge pressure.

Following are a number of problems quoted from Prof. Peabody's text book on Thermodynamics (fifth edition, p. 73). The problems are given here to check the accuracy of the diagramatic solution, and to show the manipulation of the line readings in different cases.

Problem 1:

Find the weight of 4 cubic meters of hydrogen at 30° C., and under the pressure of 800 millimeters of mercury.

Use the 40 cubic meters oblique line for convenience. Intersect with the 80 centimeter pressure abscissa. Follow horizontally to 303° (273° + 30°) absolute temperature. An oblique line through this point and the origin intersects the hydrogen weight line for the metric system at 3.41 kilograms, this being the weight of 40 cubic meters. The weight of 4 cubic meters is one-tenth as great, or 0.341 kilograms. (Text answer 0.341 kilograms).

Problem 3:

Find the temperature at which one kilogram of air will occupy one cubic metre when at a pressure of 20,000 kilograms per square metre (147 centimeters of mercury).

Take the intersection of the pressure abscissa 147 with the volume line 10 (call it one cubic metre). Follow the ordinate horizontally to meet the oblique line passing through 10 kilograms of air and read the corresponding absolute temperature 682°, being 409° C. (Text answer 410° C.)

Problem 4:

Oxygen and hydrogen are to be stored in tanks of 1.59 cubic feet capacity each. At a maximum temperature of 110° F., the pressure must not exceed 250 pounds gauge. What weight of oxygen can be stored in one tank? What of hydrogen?

Take the intersection of the volume line 159 (increase two decimal places) with the 26.5 pressure abscissa (decrease one decimal place) and pass horizontally to 110° F. The oblique line passing through this point intersects the oxygen and hydrogen weight lines at 22.1 and 1.38 pounds respectively. Proper answers (decrease one decimal place) being 2.21 and 0.138 pounds. (Same answer in text.)

Problem 5:

A balloon of 12,000 cubic feet capacity, weighing with car, occupant, etc., 665 pounds, is inflated with 9,500 cubic feet of hydrogen at 60° F., the barometer reading 30 inches. Find the

weight of the hydrogen and the pull on the anchor rope; find also the amount that the balloon must be lightened to reach a height where the barometer reads 20 inches, and the temperature is —10° F.

Take the intersection of volume line 95 with the pressure abscissa 30. Follow horizontally to 60° F. The oblique line passing through this point intersects the hydrogen weight line for inches of mercury at 0.503 pounds and the air weight line at 7.27 pounds. The full amount is therefore 50.3 for hydrogen (text answer 50.4), and 727 pounds for the air displaced by the hydrogen. The weight of the balloon including the hydrogen is 665 + 50.3 = 715.3 pounds. The pull on rope is therefore 727 — 715.3 or 11.7 pounds (text answer 12 pounds). For the other condition of the problem the hydrogen will occupy the total capacity of the balloon. 12,000 cubic feet. To find the weight of air replaced by the hydrogen, intersect the volume line 120 with the pressure abscissa 20. Pass to —10° F. and read the intersection of the oblique line through the point with the weight-of-air line for inches of mercury at 7.08 pounds, being 708 pounds for the proper volume. The total weight of the balloon was 715.3 pounds; the amount to be reduced is therefore 715.3 — 708, or 7.3 pounds (text answer 7.5 pounds).

Problem 7:

A gas receiver having a volume of 3 cubic feet contains half a pound of oxygen at 70° F. What is the pressure?

Use five pounds and 30 cubic feet. From the intersection of the oblique line passing through 5 pounds on the oxygen weight line with the 70° F. abscissa, pass horizontally to the 30 cubic feet volume line, and read the corresponding absolute pressure, 29.5 pounds per square inch (text answer 29.6).

A close observation of the curves given in this work will show that each one of them can be traced to some form of a multiplication diagram, since there are always two factors and a product; and the multiplication diagram in its turn is based upon the simple straight-line equation

$$y = cx,$$

where y is the product, and c and x are the two factors.

At the same time, however, each one of the given curves illustrates a different method of using this equation to suit the character of the work and the relation of the factors to each other. Therefore, while the given curves can be enlarged or used directly for practical purposes, it is very essential to study the principles and follow through the given methods, which can easily be applied for many other cases of similar work.

THE ELECTRICAL INSTALLATION AT THE GARY WORKS OF THE INDIANA STEEL COMPANY.

BY E. D. MacEWING.*

The fact that the plant at Gary has been written up in detail to such an extent in the engineering press, and that this article is the outcome of an inspection visit made by the senior class to the Gary works, makes it advisable to limit it to a general description. Features of special interest of this installation as noticed at this visit will be brought out, supplemented by data obtained from various engineering magazines.

Power Plant:

The present building, housing stations No. 2 and No. 3, is 966 feet long by 115 feet wide and has a gallery 22 feet 6 inches wide extending the length of the building. Station No. 3 is in operation and station No. 2 is nearly completed.

Station No. 3 contains two 2,000 K. W., 250 volt, direct-current generators, directly connected to gas engines; seven 2,000 K. W., 6,600 volt, 3-phase, 25-cycle alternating current generators directly connected to gas engines; two split-pole rotary converters, and one 500 K. W., 250 volt exciting unit directly connected to a synchronous motor.

Station No. 2 will contain nine 2,000 K. W., 6,600 volt, 3-phase, 25-cycle, alternating current generators directly connected to gas engines; two 2,000 K. W., 6,600 volt, 3-phase, 25-cycle, alternating current Curtis turbo-generator units; two exciting units similar to the one in station No. 3, one being a reserve unit, and a 70 K. W., 250 volt motor-driven exciting unit for the turbo-generators. All generating apparatus is designed to deliver 30 per cent overload continuously.

In addition to these two stations there are two 125-cell storage batteries operating in parallel with and floating on the alternating current system, being connected to the direct current side of the converter so as to discharge at heavy load and charge at light load.

The operation of the split-pole converter is such that the voltage on the direct current side can be changed, while the voltage on the alternating current side will remain constant. The alternating current bus-bars are connected through transformers to the slip rings of the converter.

Current for the main field of the converter is taken from the exciting bus-bars, while current for the auxiliary or regulating field is supplied by a synchronously driven exciter. As there are no bus-bars through which the total output goes, current transformers are placed in each phase of every generator and are connected to the totalizing bus-bars. The slip rings of the exciter are connected through current transformers to these bus-bars. This will cause a rotating field which is held stationary by the machine, being synchronously driven in the opposite direction. The shunt field of the exciter is connected through a variable resistance to the exciting bus-bars. There

*Class 1910, Electrical Engineering, Armour Institute of Technology.

are four brushes, two of which are short-circuited, the other two being connected to the auxiliary field of the converter. The shunt field is adjusted to neutralize the field produced by the alternating current at some load on the system. With a variation of load there will be a current set up in the short circuit, which in turn will produce a field, and hence a poten-

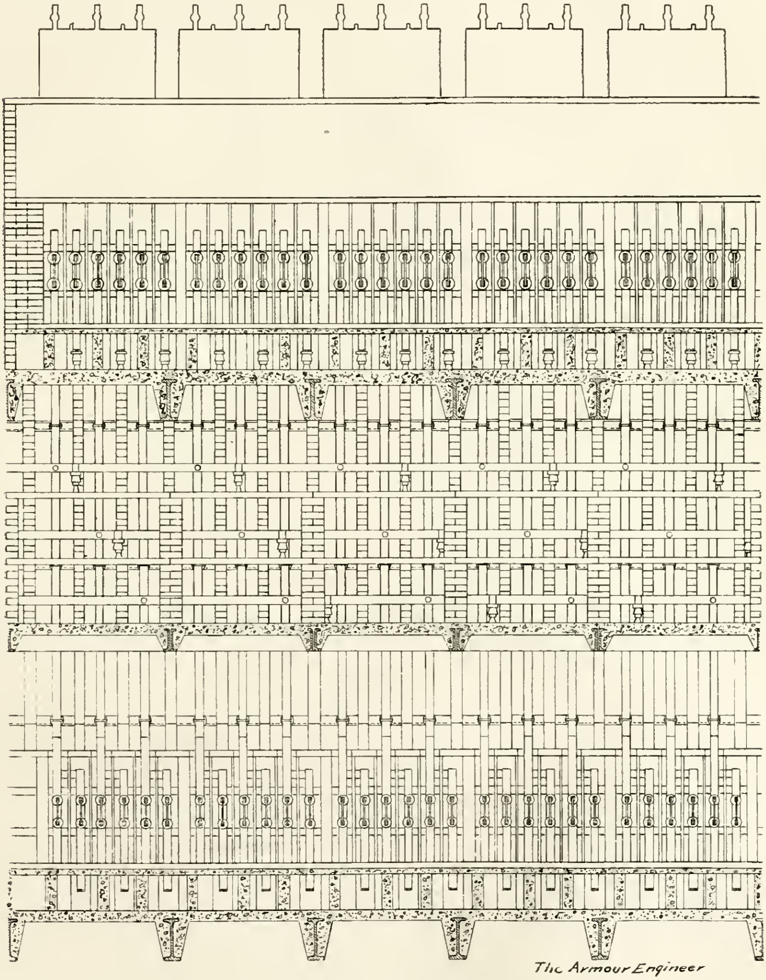


Fig. 1. A. C. Busbar Structure—Elevation.

tial across the other brushes. This will set up a current in the auxiliary field of the converter, thereby changing the flux distribution, which will change the direct current voltage, causing the battery to either charge or discharge, as the load is decreased or increased. The battery is also connected to the direct current system through boosters.

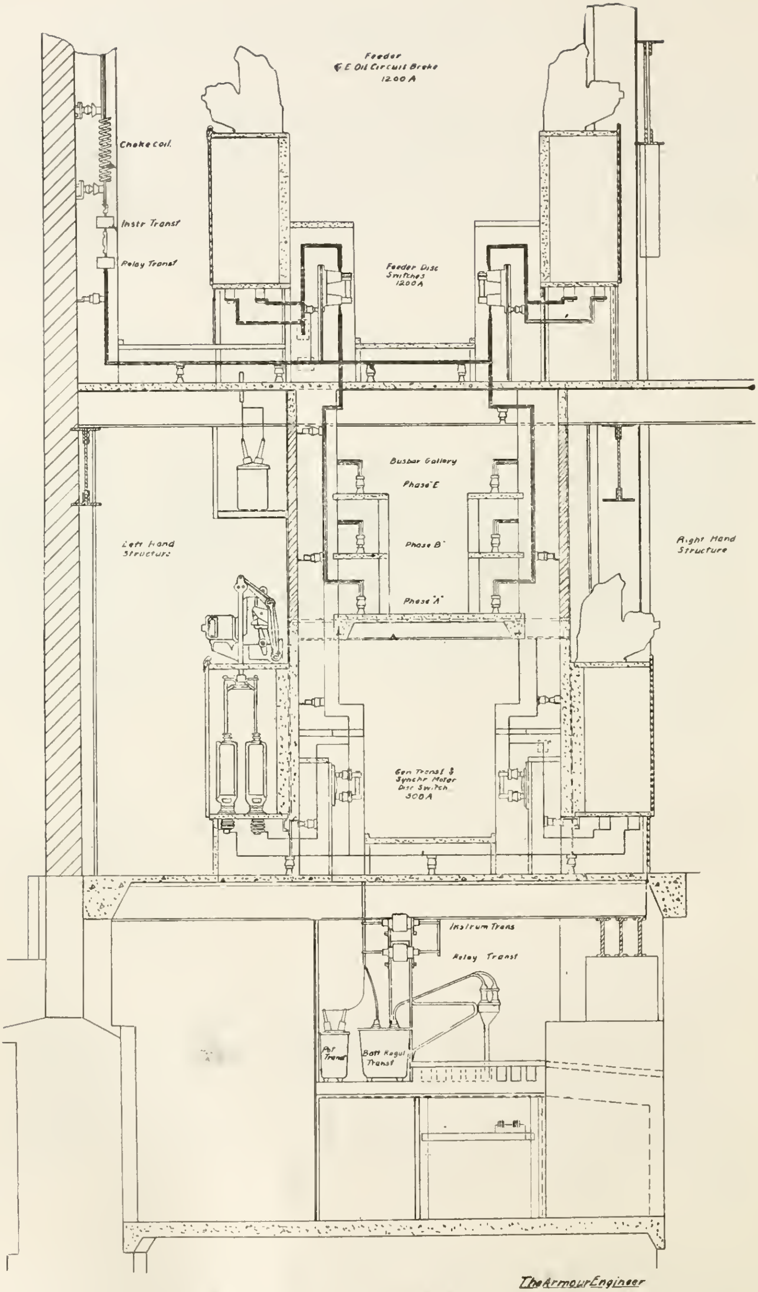


FIG. 2. A. C. BUSBAR AND SWITCHBOARD STRUCTURE—SECTION.

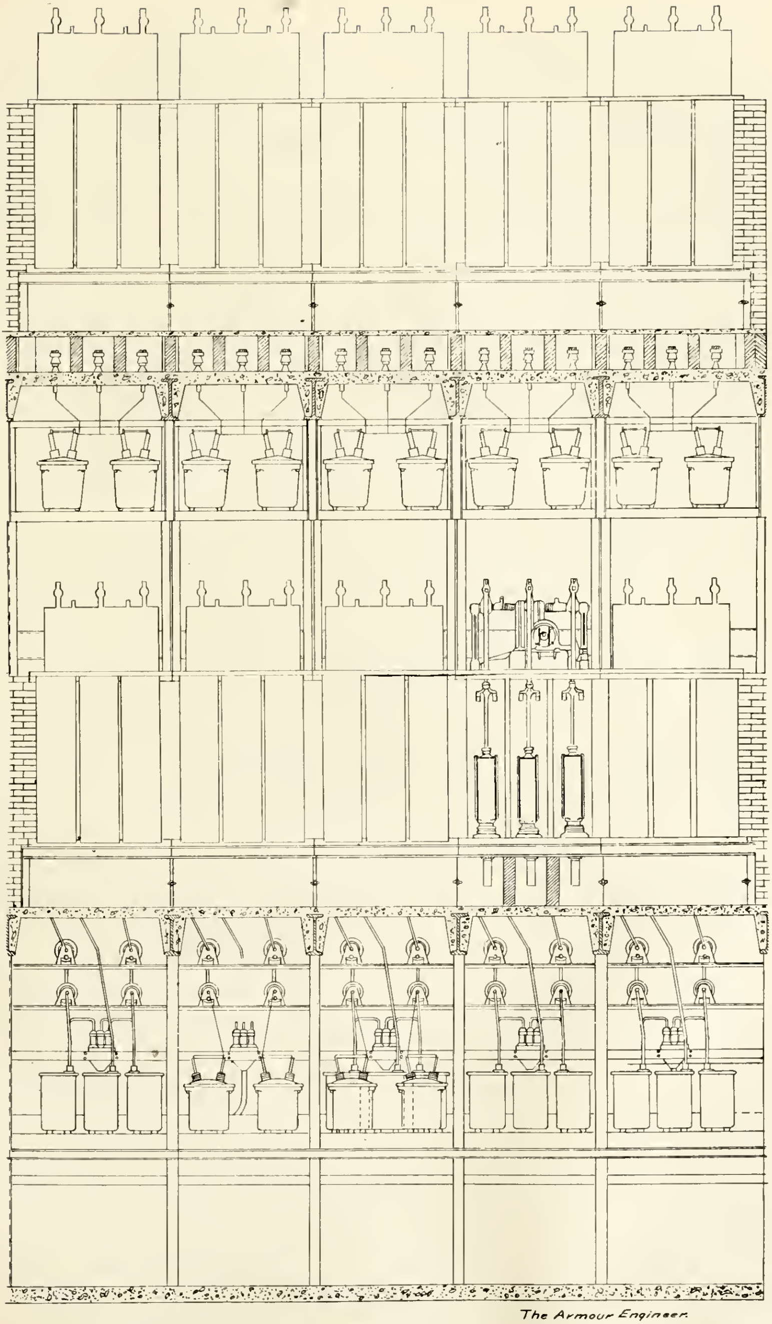


FIG. 3. OIL SWITCH STRUCTURE—ELEVATION.

When this plant is completed it will contain four stations in all. It is connected to the plant of the Illinois Steel Company at South Chicago by a 22,000 volt 3-phase line. A great deal of flexibility of operation is obtained in this way, as each station can operate singly or in parallel, or the plant can operate in parallel with that at South Chicago. There are now nine transformer stations supplying 3-phase current at 440 volts, and three substations, in operation.

Prime Movers:

Inasmuch as this is probably the largest installation of its kind in the country, and that the use of gas engines as prime movers is practically in its infancy, it is advisable to consider the gas engines by themselves. It is well to note the large fluctuations of load to which they are subjected and that continuous service is the prime essential of a plant for steel mill work. Some idea of the changes in load can be obtained from the variation of the load on the rail mill, it being from 4,000 H. P. to 19,000 H. P.

Gas from the blast furnaces, after passing through a dust catcher and two scrubbers, is stored in a holder of 200,000 cubic feet capacity, from which it is supplied to the engines as needed. Eight blast furnaces will supply a total of about 22,450,000 cubic feet per hour, about 45 per cent of which is used by the gas engines of the generating station and about 15 per cent of which is used by the engines driving the air compressors.

There are seventeen horizontal twin-tandem double-acting engines installed in the two stations, No. 2 and No. 3. They have 44 by 54 inch cylinders, being rated at 3,000 H. P. at 83 1-3 R. P. M., and capable of delivering 50 per cent overload. The ignition system is supplied with direct current at 80 volts, it being time regulated by hand wheels. An indicating device shows the time when ignition takes place in each cylinder.

The engine governor is motor controlled and the motor is controlled from the switchboard gallery. Thus, in case a generator is not taking its share of the load, the governor can be set for a higher speed, which the engine will tend to reach, but cannot, due to the synchronous operation of the generators; hence the input into the generator will be increased, which will also increase the output.

Switchboards:

The generator switchboards are all located on the main floor, while directly above are the feeder switches. Remote control is used on all operating switches. Double bus-bars are used throughout, each alternator being connected through separate oil switches to either system. The control mechanism of the two switches are interlocked, thus preventing an alternator from being connected to both bus-bars at the same time. The bus-bars, oil switches, etc., are encased in white enameled

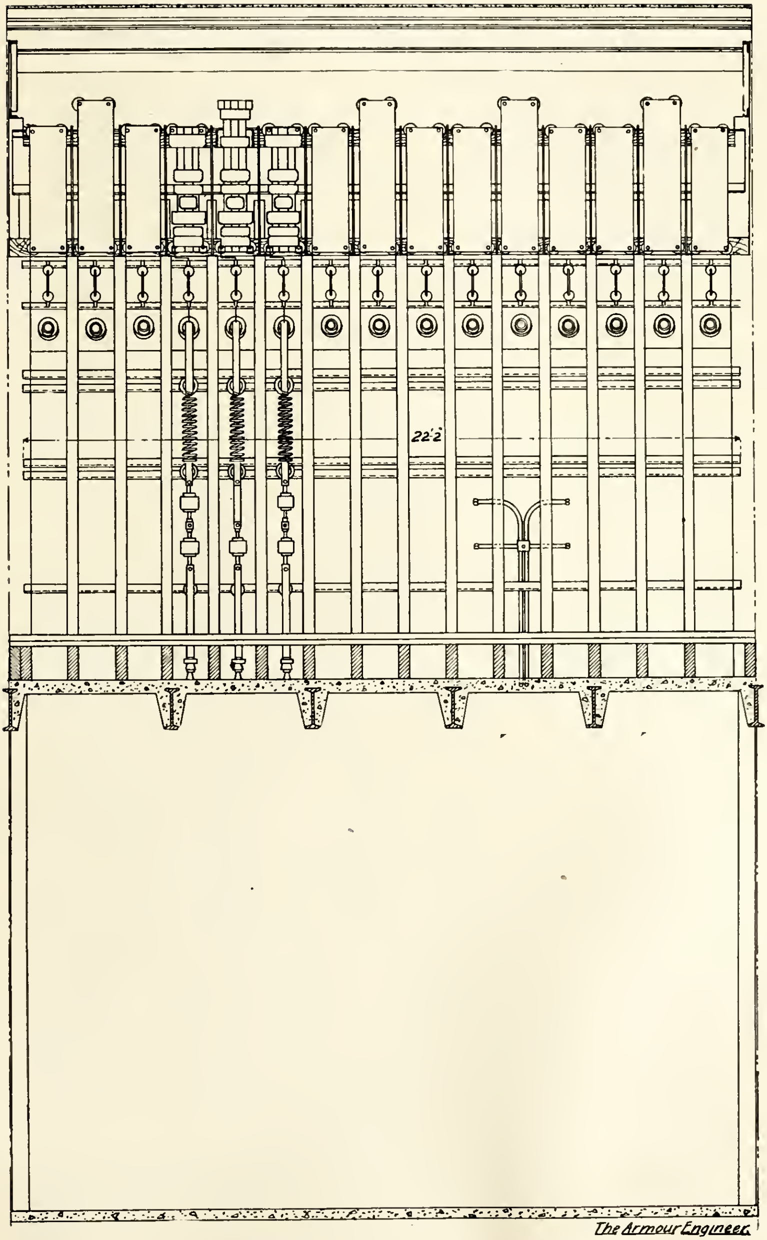


FIG. 4. LIGHTNING ARRESTERS—ELEVATION.

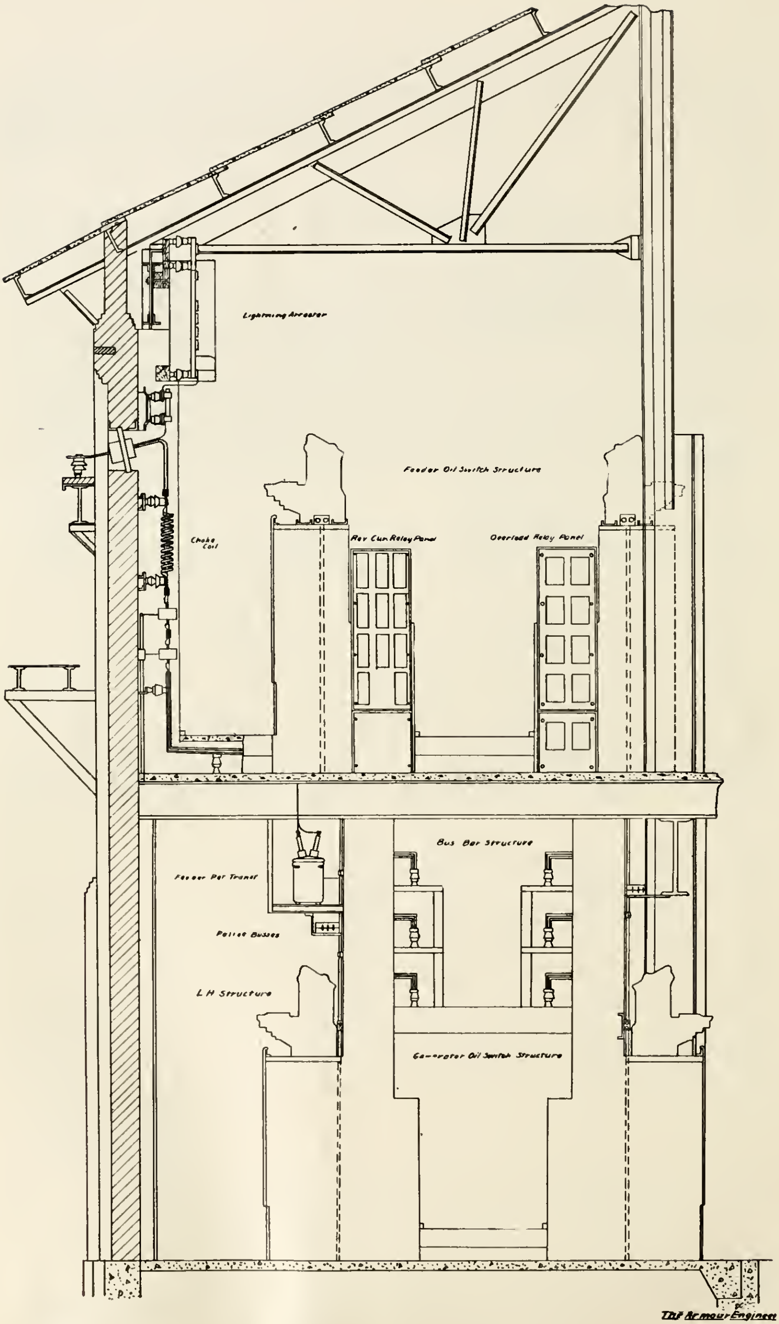


FIG. 4a. LIGHTNING ARRESTERS—SECTION.

brick compartments. The arrangement is shown in Figs. 1, 2 and 3.

The leads from the generator are carried under the main floor to the tunnel under the gallery, thence up to the generator switches on the main floor. The direct current boards are divided into positive and negative sections, the sections being back to back.

The main switchboard is divided into three sections, all of the bench board type. Section 1 contains twelve panels and controls two d. c. generators, the storage battery, the rotary converter, boosters, and the rotary exciter set. Section 2 contains nine panels and controls the exciter set and seven a. c. generators. Section 3 contains eleven panels, and controls nine d. c. and nine a. c. feeders, a 22,000 volt tie line to the South Chicago plant, and the tie line between stations.

Line connections to the feeders are all made outside of the building. Lightning arresters, part multi-gap and part electrolytic, are installed as shown in Fig. 4.

Transmission:

The alternating current is transmitted at 6,600 volts and the direct current at 250 volts. The cables are supported by double steel poles set in concrete, with cross arms between. The height from the ground to the lowest cross arm varies from 50 to 75 feet. Each pole has a capacity of 95 cables. Insulators are set 18 to 20 inches apart, and are colored white, blue and green to differentiate the phases, which simplifies tracing trouble.

Motors:

The special features of the motor installation are the three 6,000 H. P., 6,600 volt induction motors. They operate the rolls in the rail mill and are directly connected. One operates at 75 R. P. M., another at 83 1-3 R. P. M., and the third at 88 R. P. M. There are also three 2,000 H. P., 6,600 volt induction motors operating the rail mill. These motors are installed in a separate room running parallel to the mill, the shafts extending through the wall to the rolls. They are controlled from the wall pulpit in the mill, but can be shut down from the motor room.

An interesting feature in regard to these motors is the stopping. When disconnected from the line, the 6,000 H. P. motor operating at 83 1-3 R. P. M. continues to run for one hour and a half. This is overcome by introducing 250 volt direct current into one phase through an external resistance, after the motor is disconnected from the alternating current line. By this means the stopping time is reduced to one minute and forty-two seconds.

(Note: The elevations shown in the cuts are of one "bay," this being an arbitrary division through the entire plant. It is the space between columns supporting the roof.)

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The Question of Employment

At this time of the year, the question that takes the uppermost place in the minds of many of our students is that of employment. Especially is this true of the Seniors who are about to graduate, and who will for the first time enter the commercial world. Much has been said both ways with regard to the effect that the young engineer's start in the engineering world will have on his later career; but certain it is, that some beginnings will never do much toward advancing him in his profession.

Concerns with whom there are abundant opportunities for future advancement do not generally offer large salaries to the technical graduate who is just leaving school. With such a firm, the beginner is generally put through a series of positions from which he gains much experience in their classes of work, and from which the firm gets a line on the kind of work to which he is best suited. The advancement for the first year

or two is not very rapid, as employers are naturally cautious in selecting their more trusted men. The period of probation past, however, advancement comes more rapidly, and the man who has made good will find no difficulty in getting the remuneration due him.

Contradistinctive to the above statements, there is a class of positions sometimes open to the technical graduate wherein the salary to start with is very high, comparatively, but the chances of advancement are correspondingly low. The last named feature of such an opening is generally overlooked, however, as the "big money" looks very good to the man who has for four years lived as cheaply as possible amid plenty of hard work. The realization of the lack of a future in a position of this kind does not come immediately, and oftentimes, not until the holder has settled down into a rut from which it is very difficult, if not impossible, to get out. The difficulties of changing employment after a start of this kind are due to the fact that in all probability, it will be necessary to accept a lower salary for some time after the change, and without a doubt, many really good men are now located in such positions that ought to be doing bigger things. There are exceptions to both classes of positions, and it seems reasonable the graduate should use some discretion in selecting his first employment.

For the undergraduate who must needs spend his summer vacation in work, it is a wise plan to seek a position along the line of endeavor that he will eventually follow after graduation. In this manner, much of the preliminary work incident to the start after graduation can be done away with. Work of this kind is very often hard to obtain, and is apt to have a smaller compensation connected with it than short season positions in other lines. The experience obtained, however, is generally well worth the difference in the amount of money earned, though this will probably not be realized until the school has been left behind.

THE ECONOMIC IMPORTANCE OF MULTIPLE EFFECT EVAPORATION.

BY F. M. De BEERS.*

Comparatively few people realize the important relation of multiple effect evaporation to the economic success of a good many chemical industries and also to the profitable saving of numerous liquid wastes now being converted into salable by-products. Before going farther, the writer asks the pardon of those of you who know what this subject covers if he explains in brief some of the principles of evaporation or concentration as applied to liquids, when this work is done under reduced pressure—i. e., in vacuo.

As we all know, the boiling point of any liquid varies in direct proportion to the absolute pressure of the air or other gas composing the atmosphere in which the liquid is being boiled. It is only in recent years that any commercial use was made of this phenomenon and only very recently—say within ten or fifteen years—that this use was made to extend beyond a few industries. (In this paper we will assume that steam is the original source of the heat required to bring about the desired evaporation). When water is boiled and evaporated by means of steam, and fed through a closed coil in the vessel, the total heat in the steam arising is roughly equal to the heat given up by the condensing of steam in the coil after deducting for radiation losses and heat required to bring the water to the boiling point. Assuming that the steam fed to the coil has a pressure of five pounds and the pressure at the outlet is zero pounds, or atmospheric pressure, there has been given up by one pound of this steam in condensing, 975 B. T. U., of which 960 B. T. U. are represented by the latent heat of vaporization and only 15 B. T. U. because of the reduction in temperature or pressure. In other words, over 98% of the heat given up is latent heat. It has been said above that the steam or vapor arising contains practically all of this heat, as the radiation loss in a well designed and covered apparatus can be kept very low. Now if this vapor or steam were confined and kept in the gaseous state and fed to the coils in another vessel containing water, and were made to produce evaporation there, we would have a multiple effect evaporator; but in order to produce rapid boiling or evaporation in this second vessel, it is necessary that the water contained in the same be surrounded by an atmosphere having less pressure than the steam or vapor which came from the first vessel and is now being condensed in the coils of this second vessel. And in like manner the steam or vapor arising from the second vessel and having a lower

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*Class 1905. President and General Manager, Swenson Evaporator Co.

pressure than the vapor which came from pan No. 1, can be fed to the coils of a third enclosed vessel or pan and produce evaporation by gving up over 98 per cent of its total heat in condensing, provided the liquor in pan No. 3 is surrounded by an atmosphere of still lower vapor pressure—and so on, theoretically, for an indefinite number of times until zero absolute pressure has been reached.

From the above brief outline, it can be seen that the initial pressure of the steam originally used is of small moment as steam at 100 pounds gauge pressure only contains 1188 B. T. U., or 3 per cent more heat than steam at 5 pounds pressure, assuming in both cases that the steam is perfectly dry. The advantage in using higher pressure is due to the fact that more vessels or pans or effects. as they are termed, can be used. While theoretically there is no limit to the number of effects, should radiation and other losses be eliminated, the practical limit is three to four effects for most liquors, one or two for

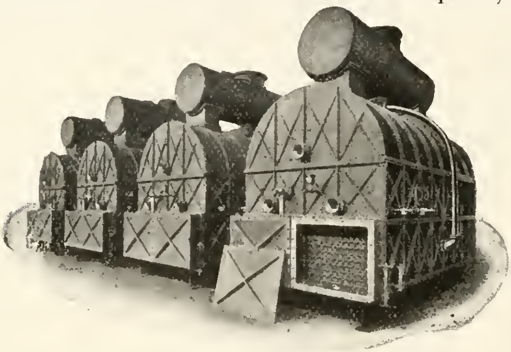

Fig. 1. A Large Sugar Evaporator.

others and five and up to eight or ten for very easily boiled materials like ordinary water when it is being purified by distillation. By this repeated use of the latent heat of vaporization, it is evident that one pound by weight of dry steam at even low pressures will remove several pounds of water from the liquid being concentrated, depending upon the number of effects installed. In other words, the economy of any multiple effect is, roughly, inversely proportional to the number of effects or separate boiling chambers in which each succeeding effect is operated under a lower absolute pressure. As practically all the work in multiple effects is done by means of exhaust steam or low pressure steam at 1 to 15 pounds gauge pressure, all of the effects are operated under less than atmospheric pressure and, for convenience, this is measured as

so many inches of vacuum by a mercury coulmn, the last effect having a vacuum equivalent to 26 to 28½ inches at sea level. One pound by weight of dry exhaust steam will remove nearly two pounds of water from any liquid in a double effect, three pounds in a triple and four pounds in a quadruple, etc. The use of evaporators is, therefore, of great importance where large quantities of water have to be removed from a solution containing salts to be recovered, or from a solution that must be concentrated to a syrupy or even dry condition.

This economy, as before stated, has not only lowered the cost of manufacture of many articles of common use, such as sugar, glucose, salt, caustic soda, glue, beef extract, etc., but has also made it profitable to save liquid wastes containing small quantities of valuable materials that could not be recovered profitably if the concentration had to be done by means of live steam in open tanks. Among these latter are glycerine, fertilizer from tankwater, tobacco extract, cattle food from steepwater in a glucose plant or from thin slop from a distillery, milk sugar from whey, iron sulphate or "copperas" from waste "pickle water" from wire and plate mills, caustic soda from "black" liquor from paper pulp mills, etc.

For example, consider the manufacture of beet sugar. The beet juice after being extracted from the sliced beets and thoroughly purified and clarified, contains, roughly, 14 per cent of sugar. This is concentrated in quadruple effects by low pressure steam and, of course, being under a vacuum from first to last, it is a closed system and none of the vapors can escape into the plant and cause damage to steel and plaster. The space required for a given capacity is also considerably less than that required for the old style of open kettle evaporation, with but a fraction of the first cost, output considered. One man can operate a quadruple effect, handling upwards of 20,000 gallons of beet juice per hour, although he usually has a helper. One pound of steam in a modern quadruple effect evaporator (similar to that shown in cut) will easily evaporate 3.65 pounds of water as against less than one pound in an open kettle. A factory of the usual size, cutting 600 tons of beets per day, will turn out approximately 70 to 75 tons of sugar from good beets, or 140,000 to 150,000 pounds. This means that an average of 140,000 gallons of beet juice has to be concentrated in the evaporator to a heavy molasses containing approximately 55 to 60 per cent sugar and other solids. This average figure does not take into account the large quantities of raw sugars which are redissolved in order to purify them further and so eventually convert everything into first quality white granulated sugar and waste molasses. The additional quantity of thin liquor to be handled or concentrated varies, depending upon the method

of operation of the superintendent, but in this paper an average figure of 76,000 gallons additional per day for a 600-ton factory will suffice. This makes a total of 216,000 gallons of a 14 per cent solution to be concentrated to a 55 to 60 per cent molasses in 24 hours in order to turn out 70 to 75 tons of white sugar.

Approximately 170-172,000 gallons, or 1,425,000 pounds of water, are removed, requiring 400,000 pounds of steam in the above mentioned quadruple effect. If this were done in open kettles at least 1,500,000 pounds of steam (pressures being equal) would be used, making a saving of 1,100,000 pounds of steam by using the evaporator. Figuring on an evaporation of seven pounds of water per pound of ordinary coal, and coal at $2.50 per ton delivered, **this saving amounts to $1,962.00 per day, or one and one-fourth cents per pound of sugar produced.** No account is here made of the added cost of boilers, buildings and equipment because of the greater steam needed, or the cost of firing and other labor and maintenance.

Of equal importance is this economy in other industries. In glucose plants they derive their power from steam turbines so designed as to deliver the exhaust at two to five pounds pressure for the evaporators, it having been easily demonstrated that it is far more economical to run this way than to have a condensing turbine and use live steam for the evaporator.

Probably the most important use for evaporators is in the reclamation of solids, both in suspension and solution, from liquid wastes. For years rod and plate mills have been polluting streams with their "pickle" water, an acid waste which, it is claimed, kills fish and is generally a nuisance. Large quadruple effects boil this down to a super-saturated solution; from which iron sulphate or "copperas" crystallizes out in pure, light green crystals. One plant alone turns out nearly 30 tons of these crystals per day and the only reason more plants do not have departments for this is because of the limited market, which is now overstocked. Copperas is extensively used, and in greater quantity every day, in the purification of water for city service. St. Louis uses over 12 tons per day, and other plants are at Pittsburg, Cincinnati, Bloomington, etc. If copperas were made from scrap iron and sulphuric acid, it would cost over $30.00 per ton to produce, as against a selling price of $8.00 per ton today. The actual cost of manufacture, considering the pickle water and exhaust steam as having no value, is from $4.00 to $5.00 per ton of dry salt, which figure includes interest, depreciation, cost of scrap iron to neutralize dilute liquor, labor, etc. If live steam had to be used in open tanks, instead of using a multiple effect, the additional cost would be $2.00 per ton (over 40 per cent more than present cost of manufacture), and a much inferior product obtained. Other im-

provements in the process of making iron sulphate from acid iron wastes which could not be made use of without having the concentration take place in an evaporator, have reduced the time of securing the finished salt from six or eight days to ten or twelve hours, thereby bringing out a very large saving in labor and overhead charges.

Consider the recovery of caustic soda from "black" liquor in a pulp mill. This is the spent liquor that has dissolved all of the resins and gums it can out of the wood, so as to get the fiber in proper condition to be made into paper. Large quadruple effects, operated entirely by exhaust steam, which was formerly wasted or simply used in feed water heaters, boil this liquor down to such a consistency that it will burn by mixing with a very small amount of fuel. The ash contains over 90 per cent of the caustic used, in the form of carbonate, which is re-causticized and returns to the process. The economy of a quadruple

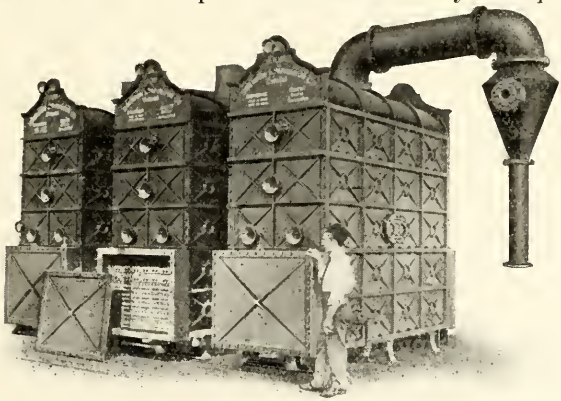

Fig. 2. Triple Effect for "Black" Liquor Recovery.

effect is the only thing that makes this recovery profitable. If the caustic in the "black" liquor was not returned to the process, it is said that large soda pulp mills would be impossible, as the cost of manufacture of soda pulp would be so great as to practically drive this very desirable fiber from the market as a competitor of rag stock, etc.

In the steeping of corn preparatory to its conversion into gluten, starch, corn oil and glucose, there remains a water containing in solution a small amount of free acid and some vegetable matters, formerly thought valueless. This was throw ninto rivers and small streams, and particularly in summer, when the water is low, was the cause of much justifiable complaint on the part of residents and municipal authorities. Unless carried

away by a swiftly moving current, it became stagnant and putrified, producing a very disagreeable odor and making the water unfit for consumption by man or beast. In modern plants this is now all saved, for the material which caused the trouble contains a large percentage of protein, which, when added to the gluten feed, makes an excellent milk producer, worth $28.00 per ton. An average plant steeping 10,000 bushels of corn per day will, according to one glucose authority, turn out ten tons of feed from the steepwater alone at a very small cost—not over $5.00 to $8.00 per ton, including all charges. Exhaust steam is, of course, used to concentrate the dilute liquor.

In the process of making edible products from the live animal in a modern packing-house, there is a considerable portion of the live weight which eventually finds its way to either the tallow, lard or grease tanks. These receptacles are usually about six feet in diameter by 12 to 14 feet long, and the material in them is cooked for a long time with live steam at 50 pounds pressure, injected directly in the mass of fat, bones, hide, scraps and offal. The object of this severe cooking is to completely break down all the small cells containing tallow, fat or grease, so as to be able to recover these valuable materials. Everything else in the tank is considered a by-product incidental to this operation. The solid animal matters containing bone phosphate and about eight per cent of ammonia were long considered valueless. Not so many years ago this material, even at our Chicago Stock Yards, was carted way and buried, and packers like Armour and Swift actually paid men to haul it away. But the solids were eventually recognized as being worth dry-and and now bring over $20.00 per ton. It seems strange, but is nevertheless true, that when a substance is in solution it is forgotten, disregarded, and the last to be saved. Up to the early '90's the water in these tanks after a cook, produced by the condensation of steam used in cooking, was allowed to run down the sewer after the lard, tallow or grease had been separated as carefully as possible. Municipal authorities complained of the odor, and different schemes were proposed to eliminate same. Filtration, purification in septic tanks, etc., were suggested and discarded because of the expense. It was finally found possible to boil it down at practically no cost in a multiple effect with exhaust steam and then to dry the heavy liquor in special dryers. The resultant product, however, had a very objectionable property. It was hydroscopic, and after exposure soon became sticky and formed large solid masses in the bins. Another waste product, our old friend "copperas," was found to be an antidote for this trouble and is now used everywhere with good results and small expense. The fertilizer made from tankwater averages 14 to 15 per cent in ammonia and, next to

dried blood, is the most valuable fertilizer made in a packing-house, always bringing over $30.00 per ton and as high as $42.00 per ton this yer. The cost of manufacture is less than $8.00 per ton, including all labor, interest and fixed charges. A similar, though less valuable, tankwater is produced at certain kinds of garbage reduction works, but even with the economic advantage of a triple effect evaporator, there is very little profit to be made, as the solids contain very little fertilizer material. The only reason garbage water is ever concentrated and the solids dried is to dispose of same in a way that is not objectionable, and do the work with the smallest possible expense. One superintendent asserts that the mixture of this dry fertilizer with their regular tankage gives a more salable product.

In the manufacture of glue, beef extract, gelatine, malt extract and other materials that are benefited by low temperature and quick evaporation while being concentrated, the use of an evaporator is not only necessary from a standpoint of steam saving, but the quality of the finished product is so much improved that evaporators are now considered indispensible.

I might continue with other examples of a similar nature, but without telling anything that will show any more clearly the economic importance of evaporators. Different liquors have varying boiling peculiarities and some are hard to concentrate, but gradually all dilute liquors will have multiple effect evporators especially designed to successfully concentrate them. Evaporation in open tanks by means of live or exhaust steam will soon be used only where very small quantities are handled, or where the liquor is of such a nature that the proper evaporator is too expensive.

In conclusion I wish to add that none of the above information or deductions is original, but all were obtained from data secured by the writer from men actually engaged in each industry mentioned.

SOME ACHIEVEMENTS OF ANCIENT ARCHITECTS.

BY THOMAS E. TALLMADGE, B. S.*

The science of civil engineering and the consequent discovery and utilization of steel in construction, or more particularly the invention of the steel framework and truss, has made of our great buildings of today engineering problems readily solved by the average civil engineer. The architect, confident in the security of his steel skeleton, runs up the height of his building forty stories or more, or spans spaces of several hundred feet without a qualm. He is chiefly concerned as an architect with the dressing, or the garment which he will apply to his great steel cage, and which he hopes will make it comparable in beauty to the great monuments of the past. We can well imagine the helplessness of the twentieth century architect were he to be deprived of steel, but let us further deprive him of steam, and with it of hoisting engines and pile drivers; let us take away from him his technical education, on which his knowledge depends, and all his books and photographs, which he finds indispensible in the preparation of his designs; also his blue prints, and make him work from such drawings as he can laboriously prepare, without modern instruments. Furthermore, let us make him work without proper compensation and in a community often on the verge of anarchy, or engaged in foreign or civil war. He would undoubtedly seek some less inconvenient method of earning his livelihood. And yet such were the conditions which usually obtained during the construction of the great buildings of the ancient world and of the Middle Ages, those very buildings to which he helplessly looks today for guidance and inspiration. Impressed as the most careless observer must be by the beauties of these monuments, how much more should the wonder of the achievement be appreciated by those of us architects and engineers who in this enlightened age, with advanced science, education and stable government, find our professional problems replete with worry and trouble. Every art, like every dog, has its day. This is not the day of architecture; it is the day of commerce and the mechanical arts.

The earliest great structures in the world are the pyramids at Gizeh in Egypt. Built earier than the fifth dynasty, these remarkable buildings must be about 6,000 years old, and the most recent investigations would make them 1,000 years older. Kindly notice that up to fifty years ago we were taught that Adam was created 4,000 B. C. and the flood occurred 3,000 B. C.!

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The great pyramid, built in an age generally regarded as prehistoric, is 482 feet in height, 768 feet square and covers 13 acres. It has an error of only six-tenths of an inch in the sides of its base, and 12 seconds in its angle! How were these enormous piles erected? We do not know.

Hardly less imposing than the pyramids are the works of the Kings of the New Empire, particularly of the 18th and 19th Dynasties. Greatest of their monuments is the magnificent temple-palace at Karnak. Some of its features are an avenue of sphinxes, 810 feet long. Enormous pylons lead through a fore court 332 by 269 feet in area. Through another pylon the famous hypostyle hall is reached, containing 12 columns 75 feet high, and 122 lesser ones. Numerous other courts, halls, etc., follow in succession, making up the most colossal ecclesiastical establishment in the world.

Of the work of the Assyrian architects little is left, but the fame of their buildings still exists. The great Temple of Baal, or tower of Babel of the Bible, was pyramidal in shape, 600 feet square and 600 feet in height—higher than the Washington monument or the Cathedral of Cologne.

One of the famous buildings in history was Solomon's Temple, built 1000 B. C. at Jerusalem. We know that it was small, but that it was marvelously enriched and decorated; that the interior was of cedar, and that the ornaments were in beaten gold. The building was destroyed about 500 B. C. by Nebuchadnezzar.

In Greece, of the buildings built on the Acropolis in Athens about 400 B. C., we find nothing to astonish us in their size, but in their perfection of proportion, detail and execution, all architectural critics have united in the unqualified opinion that no building built since has approached them. So acute was the Greek eye to beauty that in the Parthenon, in order that they might appear straight, the main lines, vertical and horizontal, are made of delicate hyperbolic curves, thereby correcting the optical illusion of the sunken appearance of the true right line. The joints are so accurate that in places it is claimed that the stones have actually reunited, and portions originally divided have become monolithic! It is hardly necessary to say that such methods are not employed today, and incidentally such results are not achieved.

The Romans were the Americans of the ancient world, and we find the same genius inspiring their building operations as is dominant with us, but here again they surpass us in many respects at our own game, as in the size and solidity of their edifices. Moreover, they had to invent most of the forms which we employ as a matter of course. The arch, the vault,

both barrel and groin, the dome and concrete, yes, reinforced concrete construction, though reinforced with tile and not iron, are all Roman devices.

Rome, the capital of the empire and the greatest city in the ancient world, presented to the eye of the visitor in the third century A. D. a vision of municipal splendor absolutely unknown to us and the like of which we shall never see. Rome was the capital of the world, and all nations paid their tribute in gold and silver. Each Roman emperor curried favor with the populace by building newer and grander buildings, until Rome became a city of marble and the vast treasury of the world. The most important features of the city were the forums or civic centers. These consisted of open paved spaces, surrounded by temples and basilicas. The open space was adorned with statues. Real estate was costly in the neighborhood of the forums. Emelius Paulus paid $2,400,000 for the land alone on which he built his famous basilica, and Julius Caesar, one hundred million of sesterces, $44.45 per square foot, for the land on which he built the forum bearing his name. Of the forums the greatest were the Roman Forum, the Forums of Augustus, Julius Caesar, Nerva and Trajan. To describe the latter is sufficient. To make a place for it, a rocky ledge was cut away, 140 feet high and containing 24,000,000 cubic feet of earth and rock. The forum comprised seven different sections, a great square, a basilica, a library, two hemicycles, a monumental column and a temple. It was considered one of the marvels of the world—"singularem sub omni coelo structuram." The five forums together contained thirteen temples, three basilicas, eight triumphal arches, the house of parliament, thousands of life-size statues, and porticos over a mile in length. Hardly less than the forums in magnificence were the baths. At the end of the third century there were in Rome eleven public baths and 926 conducted by private ownership. The baths of Diocletian could accommodate at one time 3,600 people, and the baths of Caracalla, 1,800. They were in fact gigantic clubs, and furnished libraries, concerts, gymnastic exercise, dramatic and literary entertainment, restaurants, etc. The magnificence of these establishments cannot here be described. They have furnished the chief mines from which the museums of modern times have been enriched with ancient works of art. Nor is there space to mention the colonnades by which one could walk from one end of the imperial city to another without exposure. Those in the Campus Martius alone contained 2,000 columns, with an extent of 4,600 yards. The columns were of the rarest marbles, and the pavements inlaid with jasper and por-

phyry. We have no building today comparable to the Colosseum, seating 87,000 spectators, or the Circus Maximus, which seated 285,000, or the Circus Flamimius with its 150,000. In the Coloseum were held the gladiatorial shows, and in the circus, the chariot races.

Of the engineering feats of the Romans perhaps the most impressive are the aqueducts. Of these there were fourteen at Rome, with a total length of 360 miles, supplying the city with 54,000,000 cubic feet of water a day. Many of these aqueducts were tunnels. We have an account of the boring of the one at Monte Affliano. The tunnel is seven feet high by

Fig. 1. The Colosseum.

three feet wide, and is three miles long. The tunnel was begun simultaneously at the two ends and met exactly in the middle, on July 3, A. D. 88! What is true of Rome is true in only a less degree of the architectural magnificence of the cities of the empire, now in ruins or utterly returned to dust.

There is no space to mention here the glories of Alexandria, Ephesus or Baalbec. We gaze in wonder at the "trilithon" of the Temple of the Sun at Baalbec. Three stones, each about 63 feet long, 12 feet high and 11 feet thick, weighing about 700 tons apiece are resting on the temple wall 25

feet above the ground! How were they transported from the quarry, five miles away, and how were they placed in position? For the 500 years or more after the fall of Rome in the fifth century, these stupendous structures were without doubt a cause of wonderment to the barbarians and their descendants of the dark ages. At any rate little was done till after the

Fig. 2. Amiens Cathedral.

year 1000, the millenium, the "dies irae" which should signalize the end of the world. That date happily passed. The builders again took courage and started the construction of buildings which were to develop into the glorious Gothic of the thirteenth century.

The Gothic cathedrals of the 13th century stand at the pinnacle of human endeavor in architecture, side by side with the Greek Temple of the Periclean Age. They typify, glorify and render incarnate the extatic faith of the middle ages. They are causes of wonder to us from the points of view of art and science. The architect realizes in contemplation of the have at Amiens or the facade at Notre Dame, that such perfection of architectural expression is utterly beyond him or his age.

The 20th century has turned to other forms of human endeavor to express its genius. Architecture is no longer the physical expression of the spirit of the age. Therefore, we cannot hope to rival these glorious monuments.

Hardly less of interest and wonderment to us, are the engineering and structural feats these builders, 600 years ago, performed.

A Gothic cathedral depends entirely for its stability on the equilibrium established by opposing members. The tremendous heavy stone vaults of nave and aisles tend to push the walls out, the great flying buttresses tend to push them in, and thus the combatants stand immovable in stony deadlock through the centuries. The stereotomy of the vaults is most complicated, and requires for its successful accomplishment, great technical skill. Problems of centering and staging, hoisting of material, etc. were far more serious in those days than now. The people were poorer, and material was expensive. The country was rent with feudal warfare, and yet in Europe in the hundred years between, 1175-1275, thirteen cathedrals of the first class were built in France alone, and the activity in England, Germany and Italy was scarcely less.

With the invention of printing and the consequent dessimation of books, we find architecture showing the effects of a mortal wound; her sceptor as the ruler of the minds and hearts of the people, has been wrested from her.

The Renaissance or the rebirth of classic architecture and ideals, has given us many great and beautiful monuments, some of them comparable to those we have been considering in their capacity to excite wonder and admiration, though the days of architecture as a grand art were obviously over. The men of the Renaissance are essentially modern, and in a sense the Renaissance is still the aesthetic, and social era in which we live. We cannot therefore, attempt to discuss its monuments, and keep within the boundaries of the title of this essay. Let us then pause in our 20th century complacency, sleek with our material prosperity, and our modern improvements and realize that our ancestors even without our advantages did some things better than we do them, and that assuredly "there were giants in those days."

FACTORY POWER.

BY TRACY W. SIMPSON.*

The power plant of a modern industrial establishment is so closely related to the factory system of which it is a part that it offers many features of interest having no counterpart in central stations for supplying railway or lighting load exclusively. The combination of power and lighting supply, together with exhaust steam for heating, is almost universal, and in most cases there are also other services, such as compressed air, live steam for boiling tanks, fire protection apparatus, hot water circulating system, low pressure water service, watch alarm, refrigerating system and fuel oil supply for forge shops, all of which are under the supervision of power plant operators, and which constitute an intimate part of a factory power system. In addition to the diversity of service rendered, operating conditions are often peculiar and intimately dependent on factory conditions. For instance, it is often expected that the power plant will use for fuel various factory wastes, such as sawdust, wood cuttings and tanbark, in addition to coal, and it may be necessary to operate the plant amid smoke and chemical fumes which have a deleterious effect on commonly used construction materials. It is apparent that the situation is complicated and requires intimate association with factory processes and systems in order to properly correlate these diversified services and requirements. The following is not an attempt to cover with any completeness the entire subject, but considers certain isolated points which may be of interest to those studying industrial power projects with reference to modernizing or new construction.

Power Supply.

The many advantages of electric drive bring this method forward as best in nearly all cases, whether direct current or alternating current, depending upon the extent to which variable speed must prevail. The usual proposition will prove best adapted to alternating current, except for a few machines, such as cranes, hoists, elevators and the like, where builders recommend and practically insist upon the use of direct current motors of the series or compound type. It has been customary to install a converting outfit for supplying direct current for this purpose, but this has often been an unnecessary complication. It is now the prevailing trend to discountenance crane and elevator builders and install induction motors, and in any particular instance where the fluctuation of load is prohibitive, a suitably proportioned flywheel on the motor

*Class 1909.—With International Harvester Company, Weber Works.

shaft will form a satisfactory remedy. The low grade of labor operating hoists, elevators, etc., is sure to cause a heavy maintenance of controllers of the finger type, and most satisfactory results will occur if, for elevators, an induction motor is belted direct to an old-style belted elevator outfit with manually operated shifting sheave. The character of power installations should be simple and rugged. Refinements which may be of value in hotel or office building installations have no place in factory layouts.

The system of supply may be either 25 or 60 cycles. The latter will usually be cheaper if the factory contains high speed machinery and group drives, such as would occur in textile mills or wood working plants in which motors of 900 or 1,200 revolutions per minute may be used. Arc lamps are not satisfactory on 25 cycle current, unless large size flaming arcs are used; also a local condition, such as the desire to standardize with the system of a local supply company, may determine which value is desirable. Voltage has been standardized at 480 volts for medium size plants and at 2,300 volts for plants having a majority of motors larger than 100 horsepower.

Estimates of Future Load.

Changes of power equipment are usually coincident with factory enlargement, and to decide the best size of units requires a knowledge of the immediate load on completion of the factory changes and also some idea of the future increase, say ten or twelve years hence. For the case of a factory manufacturing a uniform product, such as a twine mill or tannery, a procedure giving very close results is as follows:

Determine the present rate of manufacture of the product, and, from conference with the factory manager, make an estimate of the future production. Determine the net horsepower output from the present power plant at the machines by indicating the engines at normal load and at shaft load. Increase the net load thus determined proportionately with the increase of factory product output to give the net load at the machines in the future. Adding to this amount all losses in group drives and electrical apparatus, which are easy to estimate, gives the normal load at the power plant in the future which it is reasonable to expect will occur with increased factory production. This result must be modified either high or low in case any change of method involving increase or decrease of the power per unit of factory output is contemplated. For instance, wood working plants are very generally changing exhaust fans from high speed to low speed type, with considerable reduction of power. A recent comparison of records of net indicated horsepower to machines during a long period of years showed

it in amount to increase very closely proportional to the increase of factory production, and proves the assertion that this method is warranted for estimating the future load in this instance.

The method is a rational one for determining future load, but the result should be checked by an independent study of the power required by each machine and the probable number of machines to be operated at any one time. In case of electric drives, the ratio of the horsepower of motors installed to the rated capacity of generators supplying them varies from about 5, in case of some individual drive factories, to as low as 1.3 for factories having heavy machinery in group drives, in which the driving motor size has been closely apportioned.

As to the lighting load, an average well lighted factory having about half its floor space in warehouse and for storage will require power of about .25 watt per square foot of total floor space (on basis of carbon filament lamps), whereas rooms devoted to manufacturing having good general lighting and also localized lighting at machines may require .5 watt per square foot of floor space. It is only occasionally that all lights will be burning simultaneously. An average of counts in a factory manufacturing wagons shows the following results in percentage of lamps in use at varying times of day:

	Percentage lamps burning to lamps installed.
Day load (sunshine)	12
Day load (cloudy)	23
Evening load (5 p. m., winter day)	88
Night load (factory not operating)	9

Heating System.

For direct radiation in manufacturing buildings, average practice provides one square foot of radiating surface to each 150 to 200 cubic feet of volume in latitude of Chicago, the actual value depending on exposure, etc., and one square foot to 500 cubic feet of volume for warehouses, forge shops, etc.

The most preferable method of installing direct radiation in mill buildings is by means of flat coils placed down three feet from the ceiling, heat being transmitted to the room on the principle of convection. Forge shops, crane bays, etc., having louvres, are not well adapted to this means of heating, since convection is disturbed by openings and ventilation. An indirect system having both pressure and exhaust ducts is the most desirable system in these cases. Steam for heating in dry kilns, indirect systems, boiling kettles, etc., must be estimated for each specific instance.

Three pounds of exhaust steam per hour is an average value for condensation per square foot of radiating surface in

building heating service. This checks closely with average results in a factory having dry kilns, indirect and direct radiation by test and by calculation, and is the value used by a large corporation, which apportions the burden by a machine hour system, and it is necessary to charge each room with its proportion of exhaust steam used for heating.

Number of Units.

In older belt and rope driven factories, it was common practice to use one large engine unit of sufficient capacity for the entire load. From the standpoint of reliability, this arrangement was poor, but was permissible for the reason that liability of shut-down due to shafting or belts was greater than the liability of engine failure, and accordingly the expense of duplicate engines was usually unwarranted, since it was not feasible to duplicate the belting system. Accordingly, shut-downs were more or less expected and regarded merely as a necessary evil of factory operation. Compared with a modern electric central station, the standard of reliability was very low.

With the advent of electric drive this same method of a one unit generating plant was continued, and in many early factory installations complete dependence was had on one generating unit. However, it was rapidly discovered that although the total number of shut-downs was on the decrease, yet the percentage due to engine and boiler trouble increased, and with a growing appreciation of the cost of a shut-down due to loss of time, waste of product in manufacture, etc., a higher standard of reliability was demanded of power stations. Also, for another reason, engine room break-downs became increasingly obnoxious. The average factory operating ten hours per day has its power plant employe on a twelve-hour shift, whereas common practice in electric light and railway stations is an eight-hour shift. Accordingly, Sunday and night work in repairs on the disabled unit is a disagreeable and manifestly unfair task to set for men already held to a twelve-hour shift.

It is now recognized that a factory power plant should incorporate in its design sufficient insurance against shut-down so that repairs may be made by the operating force without having them resort to night work. An early expedient was the application of a high pressure cross connection to low pressure cylinder in case the unit was a compound engine. It is not necessary to install complete duplicate generating equipment for the purpose of reliability insurance, since careful attention to design and choice of size of units will provide perfect insurance by making use of overload capacities of generators, engines and boilers. A factory power plant is particularly

well adapted to insurance against shut-down by taking advantage of this flexibility of the steam-electric combination, since a factory power load is reasonably uniform and of easily predetermined amount.

A recent example of the application of this principle occurs in the experience of the writer, in which a factory load averaging 750 K. W. during the day was to be supplied, together with an additional load of 120 K. W. for lighting during two hours of early winter evenings. For this purpose it was recommended that three 300 K. W. units be installed and that all units be operated, being loaded normally 84 per cent during midday and approximately fully loaded during winter evenings. Thus, in case of accident to one unit during midday, the two remaining will be loaded to but 25 per cent overload, and to but 50 per cent overload in case of shut-down during a winter evening. Operation can be continued indefinitely with safety under these circumstances, and one unit may be shut down for minor repairs or any other reason whenever necessary. The only disadvantage attending the operation of two units is the reduced economy and greater wear and tear due to overload condition.

The same principle can be extended to piping and boiler layout, so that reliability insurance can be obtained merely by careful attention to overload guarantees, size of units, etc. With piping systems it is only necessary to add a sufficient number of valves in the headers to permit sectionizing and isolating damaged portions, so that but one-third of the plant, in the above mentioned instance, need be shut down for renewing or repacking any valve, gasket, or other repair. When facility is provided for repair work in the daytime the quality of work done is far more permanent and reliable than is a simlar job accomplished under strained conditions in overtime work. A recent comparison of estimates of cost for piping systems having this feature of liberal valve layout to insure against shut-down, with a more meager equipment having just enough valves to operate the plant, showed an excess in cost of piping the former arrangement over the latter of but 15 per cent. This is a small price to pay for absolute insurance against shut-downs from any single piping break-down.

With reference to boilers, it is only necessary to note that it is a reasonable operating condition for a boiler to be out of service for cleaning, and accordingly the size of boiler units should be such that the enforced shut-down of a second unit will not overload the remainder more than, say, 15 per cent, which is a usual forcing limit. That is to say, a shut-down of a boiler for cleaning is not considered in the same sense as a break-down, but is to be expected and provided for in the

station layout. The extent to which it is advisable to adhere rigidly to this idea depends on the purity of feed water supply.

The division of the total installed capacity into three or four units or divisions and utilizing overload capacties for the purpose of insurance against shut-downs is a measure only capable of adaptation to large size factory power plants, say in which individual units will be not less than 400 or 500 horsepower each. In smaller plants, on account of higher cost per horsepower of small units, it is preferable to install full duplicate generating equipment.

All units should preferably be of uniform size, since a slight economy loss due to having units not exactly fitting the load curve will be more than counterbalanced by desirability from the standpoint of spare parts, by having all similar equipment of identical type. A possible exception to this plan is provision for a small unit for handling lighting load at night, when the load is usually but a few per cent of the day load in average factory installations, but even in this case an arrangement so that the exciter engine can supply power to the line by means of a double current generator, or by operating the motor driven exciter unit as an inverted set, will be an efficient method of handling night load. For this purpose the alternating current end of the motor driven exciter should be preferably a self-starting synchronous motor, capable of inversion as a generator.

Estimate of Fuel Supply.

In a large number of cases, there is refuse fuel supply to utilize in addition to coal, which fact has an important bearing on economic studies of types of equipment. Refuse may be in the form of wood, tanbark, foundry waste heat, gas, etc., and it will usually be found by inspection whether the margin of coal used as make-up is sufficiently large so that economic savings of one type of unit over another may be measured by saving in coal, which is the purchased part of the fuel. In many cases a high grade of power equipment is not warranted, since by its use the margin of coal is not only eliminated, but waste fuel is being saved. It is not desirable to go to a higher expense for first cost of more economical equipment beyond the point where coal margin is wiped out by its use.

However, it is usually necessary that an estimate of waste fuel be made, and determination is unusually difficult, since wastes come erratically and with no means of measurement. In such cases an evaporative test of the plant in average condition, together with measurement of coal used during the test, will give the evaporation due to refuse by difference, by assumption of reasonable furnace and boiler efficiencies, as dictated by local conditions. The amount of refuse delivered per

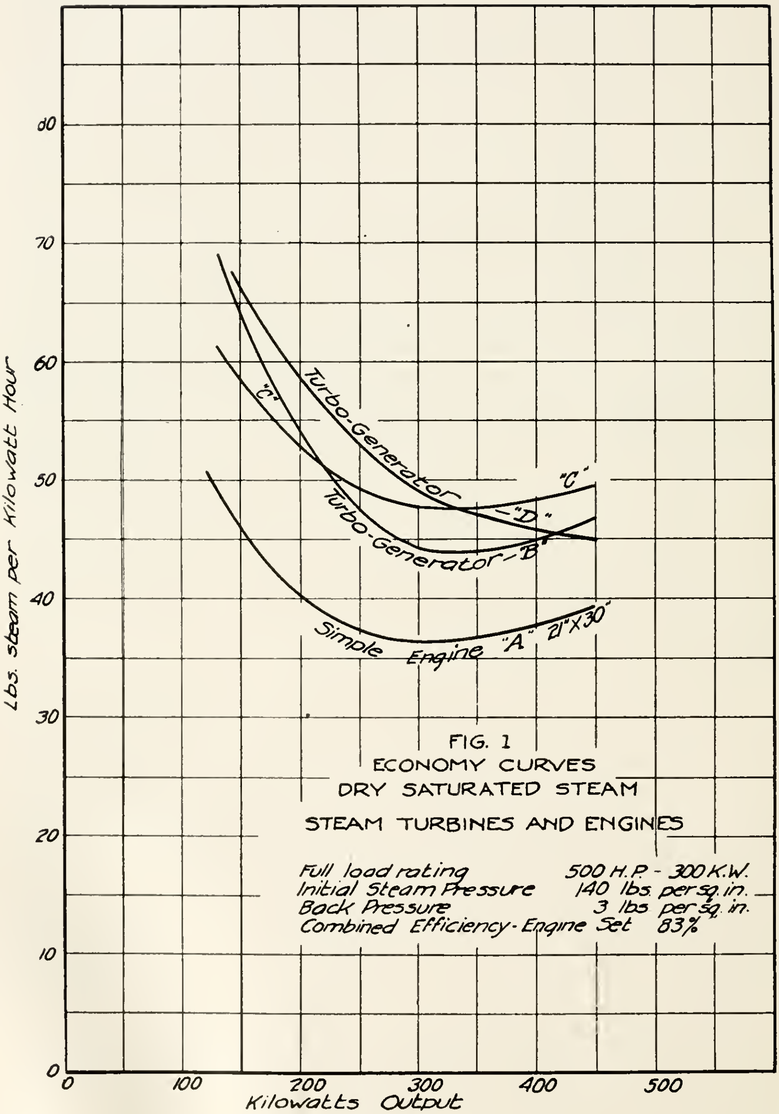
Lbs. steam per Kilowatt Hour
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
Kilowatts Output
Turbo-Generator "D"
"C"
"C"
Turbo-Generator "B"
Simple Engine "A" 21" X 30"
FIG. 1
ECONOMY CURVES
DRY SATURATED STEAM
STEAM TURBINES AND ENGINES
Full load rating 500 H.P. - 300 K.W.
Initial Steam Pressure 140 lbs. per sq. in.
Back Pressure 3 lbs per sq. in.
Combined Efficiency - Engine Set 83%

FIG. 1.

day will then be directly stated in terms of its evaporative power, which is as reliable as its measurement by pounds or cubic feet and its subsequent conversion to evaporative power on the basis of calorimetric tests.

Type of Prime Movers.

A recent comparison of steam engines, simple and compound, with steam turbines, is presented in this connection as showing features of these units and their respective performances for non-condensing operation in a plant having available considerable refuse fuel, and an exhaust steam demand of varying and heavy proportions.

Fig. 1 shows guaranteed economy curves for three types of non-condensing steam turbines, and an average guaranteed economy curve obtained from four proposals for simple engines, and also for cross-compound engines. Proposals were all based on identical performance specifications and refer in each case to a 500 H. P. unit direct connected to a 400 K. V. A. alternating current generator. Engine speed is 150 revolutions per minute, being limited on account of floor space, which necessitated that there be used highest grade engine of gridiron or other special valve type, and the four makers whose proposals constitute the basis for curve Fig. 1 are the best American engine builders of this type of engine. All economy curves for engines are reduced to a kilowatt hour basis by means of engine and generator efficiency curves, also obtained from definite proposals.

Fig. 2 shows the hourly average demand throughout the year for exhaust steam to the heating system, which includes dry kilns operating continuously winter and summer; also such other items as steam available for heating with various types of units, refuse available, etc. Fig. 2 gives all data required for calculation of coal consumption per annum in case any type of prime mover be adopted.

Table I shows annual operating costs with various types of units on the basis of dry, saturated steam. The most difficult item of calculation is that of pounds of steam per annum, in which the heating load of holidays, Sundays and nights must be considered, as well as the load when power is required. The overwhelming advantage of simple engines for the instance cited was to be expected, but it is often desirable that definite conclusions be placed in a manner to admit of no controversy. In placing propositions before mill owners, the money viewpoint appeals most strongly, and oftentimes a tabulation similar to Table I will pay for the labor of compilation merely by saving time of argument with salesmen and other interests.

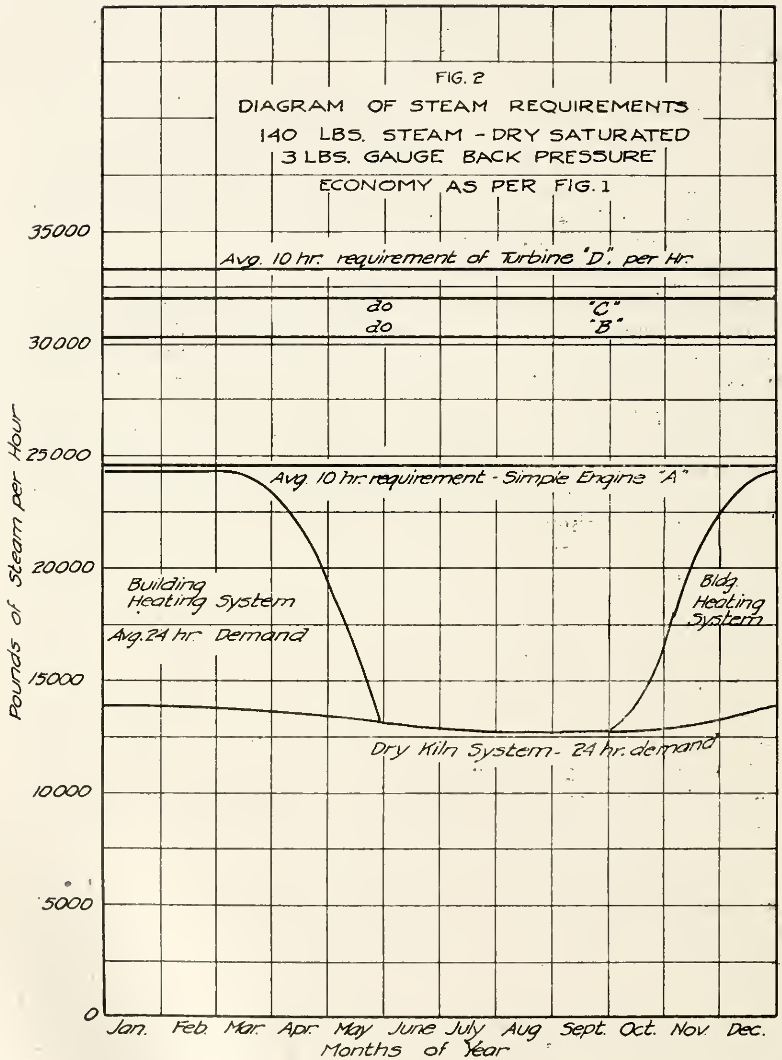
FIG. 2
DIAGRAM OF STEAM REQUIREMENTS
140 LBS. STEAM - DRY SATURATED
3 LBS. GAUGE BACK PRESSURE
ECONOMY AS PER FIG. 1
35000
Avg. 10 hr. requirement of Turbine "D", per Hr.
do "C"
do "B"
30000
25000
Avg. 10 hr. requirement - Simple Engine "A"
20000
Building Heating System
Bldg. Heating System
Avg. 24 hr. Demand
15000
Dry Kiln System - 24 hr. demand
10000
5000
0
Pounds of Steam per Hour
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
Months of Year

Fig. 2,

Comparison of Generating Units.

TABLE I.

Steam Pressure 140 lbs. per sq. in.—Dry and Saturated

1 Cost of Engines erected	$17,900	$37,100	$33,200	$32,695
2 Cost of Generators erected	13,268			
3 Cost of Foundation	1,960	990	990	950
4 Cost of Exciters	5,840	3,920	3,920	3,920
5 Total cost Generating Plant	$38,968	$42,010	$38,110	$37,565
6 Steam economy, lbs. per K. W. hr. at switchboard	36.2	44.4	47.3	48.9
7 Steam per annum from Boiler plant, millions of pounds	174.3	192.3	202.8	210.6
8 Steam from refuse per year	121.5	121.5	121.5	121.5
9 Steam to be made up by burning coal, millions of lbs. per year	52.8	70.8	81.3	89.1
10 Tons of coal burned per year	4,060	5,430	6,240	6,860
ANNUAL COSTS				
11 Fixed Charges, Generating Plant, 12% per annum	$ 4,660	$5,050	$4,560	$4,500
12 Maintenance and supplies	800	600	600	600
13 Coast of Coal per annum at $2.00 per ton	8,120	10,860	12,480	13,720
	$13,580	$16,510	$17,640	$18,820

Condensers.

The following relates to factory power plants, which have always been considered non-condensing propositions exclusively, either on account of lack of condensing water or on account of an exhaust steam demand which seemed controlling. These installations require analysis from the standpoint of a cooling tower or an evaporative surface condenser, both of which have made recent rapid strides and are now on such a definite commercial basis that performance guarantees and good deliveries are easily obtainable. An important point in common with these devices is that they are least efficient in summer, when air temperature is high. Hence if the equipment can only be used in the summer time, as is often the case in factories having building heating alone, both a low use factor and a low efficiency factor are against their installation.

The present status of the evaporative surface condenser is about as in the following tabulation, which gives sufficient data to permit of an estimate of its commercial practicability in most cases. The data applies to sizes sufficient for condensing from 8,000 to 20,000 pounds of steam per hour in summer, having brass tubes, of fan type, and arranged for electrically driven auxiliaries.

Status of Fan Type Evaporative Surface Condenser, 1910.

Steam condensed, lbs. per hr. per sq. ft. surface, differential temperature 18 degrees	2.5
Spray water evaporated per lb. of steam condensed	0.8
Cubic ft. of air per lb. of steam condensed (temp. 80 degrees F; humidity, 90 per cent; vacuum, 25 inches)	240.0
Power for fan, spray pump and vacuum pump per 1,000 lbs. steam condensed per hr. to 25 inches vacuum	1.6
Average cost complete outfit per 1,000 lbs. steam condensed per hr., 80 degrees F., 90 per cent humidity, 25 inches vacuum	\$300 to \$400

To be perfectly safe it is necessary to figure capacity on a basis of 90 degrees Fahrenheit and 100 per cent relative humidity, as would occur during a summer rainstorm. On days when the temperature is in excess of 90 degrees, the humidity will be much below saturation and the capacity will usually equal that for the conditions named. As signficant of the increased capacity due to low air temperatures in winter, a condenser proportioned on the above basis for summer conditions will have over twice the capacity in winter as in summer, or if supplied with but the same amount of steam, will produce about a 28-inch vacuum in winter as compared with, say, a 24-inch in summer.

A cooling tower outfit is a second possibility for condensing exhaust steam without water facilities of magnitude. This will cost twenty to thirty per cent in excess of an evaporative condenser in case a surface condenser is used, and about equal to an evaporative condenser in case a jet condenser is used. Cooling towers may be figured upon a rate of heat transfer of six B. T. U. per degree of differential temperature per hour in case of natural draft towers, and eight B. T. U. per degree in case of forced draft towers. With increased circulation of air, the rate increases, but the exact ratio is not definitely established.

As little water as possible should be circulated in condenser and cooling tower in order to keep sizes down and reduce cost of pumping. For minimum cost of pumping the water should leave the condenser at the same temperature as the steam entering, and the average differential temperature in the condenser will be a mean between entering water and final water temperatures. The amount of water can be decreased if the differential temperature in the condenser is increased, but for a constant inlet water temperature this will be as the expense of vacuum. The inlet water temperature is a function of the extent to which the tower cools the water, and this in turn depends on the extent of exposed surface and conditions of the air as to temperature and humidity. In this, as in the case of the evaporative condenser, 90 degrees Fahr-

enheit and 100 per cent relative humidity should be the assumed conditions when working out a design to fulfill a guarantee. The entire matter of proper differential temperatures, proper surface and vacuum is one requiring careful study and balancing of fixed charges and operating expense for the change. The daily and annual load factor has an important bearing. It is often possible to effect a very material saving in cost and size of cooling tower outfits by allowing for a reduction of vacuum in summer and not holding builders to a fixed guarantee the year through. It is essentially an engineer's problem, since manufacturers cannot but be influenced by a desire to sell a big outfit, whereas a less ambitious equipment would be better adapted to conditions. The whole matter of condenser and cooling tower economics is sufficient to tax one's ability to the utmost in the endeavor to obtain proper proportioning, and is one for decision in particular cases rather than for generalizing.

For the wetted surface of cooling towers the use of burlap curtains is a recent development which shows saving in cost over wood, tile or galvanized wire screens, and is giving good satisfaction. It is essential that water be distributed evenly over all curtains, and it is usually necessary to experiment considerably with this in view. All fan capacities should be calculated for handling saturated air, and their operation in service should be watched in order that no spray will be carried away from the top. It will usually be found that forced draft fans operate at too high speed and water is wasted by being carried out mechanically.

There also occur certain instances in which a condenser of the evaporative surface type, or of the surface type with cooling tower may be made to show a saving by considering the reduction of boiler cleaning due to ability to return condensation to boilers. The item is important particularly in cases where feed water contains heavy bicarbonate impurities which do not, however, precipitate as carbonates at the low temperature of the condenser, but will do so at the high temperature at which boilers operate. In this respect the cooling tower will be a better device than will an evaporative surface condenser, since any deposition of scale that may occur at low condenser temperature will seriously affect the latter.

SPECIFICATIONS OF THE BUREAU OF STREETS OF CHICAGO.

BY WALTER G. LEININGER.*

The ordinances of the city of Chicago provide that whenever the cost of supplies, material, etc., amounts to more than $500 they shall be bought by contract. Before a contract is entered into, specifications must be drawn and a statement of facts published in two of the daily papers for at least ten days prior to the receiving of bids.

The bureau of streets is one of the largest bureaus of the city, its expenditure per year being over three million dollars. Its line of work and its needs are more varied than those of any other bureau, and consequently the writing of specifications is one of the important and difficult problems of the bureau. During the last two years over fifty different specifications have been written, calling for everything from nails to road rollers.

Bidders, as a rule, are fair and reasonable, and will call one's attention to any impossible or unreasonable demands, or to any questionable provisions in the specifications, but there are always some who will take any advantage they can from a weak specification and try to have the bids rejected and a new letting ordered on revised specifications. It is, therefore, necessary to draw the specifications in a clear and distinct manner, so that there will be no loop hole for the bidders to claim that certain clauses in the specifications were ambiguous, and that they did not know exactly what was called for therein.

After a contract is awarded and the work commenced the contractor is constantly on the alert for extras, and this is always a troublesome matter at its best, because the engineer's idea of the reasonable cost of extras and the contractor's idea of the cost are at a wide variance.

The natural tendency, on account of the constant claims by the contractors for extras, has been to draw long and bulky specifications, wherein all the small items have been minutely detailed, and every possible contingency that might arise provided for. Consequently, most all specifications have to be studied very carefully and much time wasted by the bidder in picking out the essential clauses necessary to determine the amount of their bid.

In order to eliminate the above conditions, the matter was taken up with the law department of the city, and after a good deal of study a set of special and general requirements was drawn up and printed. The special and general requirements are essential to all specifications and are made a part thereof by attaching the printed form to each specification.

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*Class 1906. Assistant Superintendent in Charge of Street Repairs, Chicago.

The special and general requirements are usually just glanced at by the bidders, and are considered merely a matter of form. In case of a misunderstanding of the specifications or a lawsuit for damages sustained on account of the prosecution of the work, the special and general requirements are brought into prominent play, and in many cases they have saved the city thousands of dollars.

In drawing specifications, simplicity is the ideal aimed at, and very often a good deal of ingenuity is necessary to keep the specifications simple and at the same time complete enough to cover the work and do away with extras.

The following specifications are a few of the many brought out by the Bureau of Streets with satisfactory results:

SPECIAL AND GENERAL REQUIREMENTS.

Intent.

It is the intent of these specifications to provide for this improvement in a complete and workmanlike manner. The contractor to whom the work is awarded shall furnish all material, labor, tools and appliances necessary to properly conduct and complete the work according to these specifications, and anything herein omitted which may be reasonably interpreted as being necessary to such completion—the Commissioner of Public Works being the judge—shall be merged into the price bid.

Price for Each Item.

No bid will be accepted which does not contain an adequate or reasonable price for each item named in the schedule of quantities.

Personal Examination of Work by Contractor.

Bidders must satisfy themselves by a personal examination of the ground and locality where the proposed work is to be done, as to the accuracy of the foregoing estimated quantities, also as to the amount and character of the work to be done. Bidders must also make personal examination of all plans and must check the accuracy of all figures, and said bidders agree to immediately call the attention of the Commissioner of Public Works to any inaccuracies which may exist on said plans or in such figures.

Interpretation—Errors.

Any doubt as to the meaning of these specifications will be explained by the Commissioner of Public Works, who shall have the right to correct any errors or omissions in it when such correction is necessary for the proper fulfillment of its intention.

Misunderstanding of the Specifications.

The contractor to whom the work herein specified is awarded shall not gain an advantage of any misunderstanding as to the nature or amount of the work to be done under

this contract, nor shall the contractor complain of nor dispute the estimates of the engineer.

Names of Firm to be Given.

Companies or firms bidding for the work herein specified must state in the proposal the individual names and places of residence of the person or persons comprising such firm, or the officers of such company.

Notification.

If the bidder to whom the contract is awarded shall fail to appear at the office of the Department of Public Works, either in person or by agent, within two days after notice of such award is mailed to him through the postoffice of this city, or shall not, within five days after the mailing of the notice of such award, furnish the required security, his right to such contract shall thereupon be forfeited.

Character of Work.

All work shall be executed in the best and most workmanlike manner, and no improper materials shall be used. All materials of every kind shall fully answer the specifications, or if not particularly specified, shall be suitable for the place where used and satisfactory to the Commissioner of Public Works.

Patents.

All fees for any patented invention, article, arrangement or other appurtenaces that may be used upon or in any manner connected with the construction, erection or maintenance of the work, or any part thereof embraced in these specifications, shall be included in the price stipulated in the contract for the work, and the contractor must protect and hold harmless the city of Chicago against any and all demands for such fees or claims.

Contractor to be Governed by City Ordinances.

The contrator and his agents shall be governed by any and all ordinances of the city of Chicago, and by the "Rules and Regulations" of the Department of Public Works of the city of Chicago, in so far as the said ordinances of the said "Rules and Regulaions" bear upon the prosecution of the herein specified work.

Damages and Obstructions.

All loss or damage arising out of the nature of the work to be done, or from any detention or unforeseen or unusual obstruction, or from difficulties which may be encountered in the prosecution of the work, or from the action of the elements, shall be sustained by the contractor.

Skilled Labor to be Employed.

The contractor shall employ a sufficient number of competent skilled workmen—the Commissioner of Public Works being the judge—to do this work. Whenever the Commis-

sioner of Public Works shall inform the contractor, in writing, that any person on the work is, in his opinion, incompetent, unfaithful or disorderly, such person shall be discharged by the contractor and shall not be employed on the work again.

Safeguards.

The contractor agrees to guard the public effectually, by all means in his power, from liability to accident in consequence of his operations in the fulfillment of this contract, both by night and by day. The contractor further agrees that he is to be held responsible and will pay any damages which may be awarded to any person by any court of competent jurisdiction because of such accident or accidents. The contractor to have due notice of the pendency of such suit.

Bond.

The contractor shall execute and deliver a bond with good and sufficient sureties, to be approved by the Commissioner of Public Works, in such amount as is required by the ordinances of he City of Chicago, conditioned to insure the performance of the work in the time and in the manner required in the contract, and also to save and indemnify and keep harmless the said city against all liabilities, costs and expenses, which may in anywise accrue against the said city in consequence of the granting of the contract, or of the doing of the work thereunder, or which may in anywise result from the carelessness or neglect of the contractor, or his agents, employes or workmen in any respect whatever, and conditioned also that if any judgment be recovered against the city by reason of anything done by said contractor or his employes under said contract or the omission of anything required by said contract, and when due notice has been given the contractor of the pendecy of such suit, such judgment shall be conclusive against the contractor and his sureties on such bond, not only as to the amount of damages but as to their liability, and conditioned also for the payment of all claims or demands whatsoever, which may accrue to any person who shall be employed by such contractor, or any assignee or sub-contractor of such contractor in or about the performance of the contract.

Arrears.

No bids will be accepted from, or contract awarded to, any person, firm, or corporation, who is in arrears or in default to the City of Chicago upon any debt or contract, or who is a defaulter, as surety or otherwise, upon any obligation to the City of Chicago.

Non-Prosecution of Work.

If at any time, in the opinion of the Commissioner of Public Works, any contractor, not being hindered by natural cause beyond his control, shall fail to maintain a sufficient working

force of men or appliances, or if it shall become evident to the Commissioner of Public Works that the work is not being prosecuted with proper diligence to complete it within the contract time, the Commissioner of Public Works may direct the contractor, in writing, to employ more men and furnish additional material and appliances; and should the contractor fail to do so within three days after such direction in writing, then the Commissioner of Public Works shall have the right to employ additional labor and appliances and to procure necessary material at such cost as he may deem necessary, and the total cost of such additional labor, material and appliances may be deducted from any money due the contractor; or if, in the opinion of the Commissioner of Public Works, it is necessary to do so, he shall have the right, after such notice to the contrator, to take possession of the work and the plant, tools and materials of the contractor, and to prosecute the work under this contract to completion by men employed by the Commissioner of Public Works, and shall employ such labor and procure such material and such additional appliances as he may deem necessary to finish the work in a workmanlike manner and within the contract time, and all the expense of such construction under the orders of said Commissioner of Public Works shall be deducted from the compensation provided to be paid the contractor under and by the terms of this contract. Provided, however, that said Commissioner of Public Works may at any time, in his discretion, when he thinks the contractor is not proceeding properly with such work, annul this contract and proceed with the construction of the work, either by letting the contract after further advertisement according to law, or by completing it as hereinabove specified.

Forfeiture of Contract.

In case of the forfeiture of the contract, or in case of its abandonment by the contractor for any cause whatsoever, the Commissioner of Public Works may, if he deems best, take possession on behalf of the City of Chicago of all tools, machinery, apparatus, appliances and plant of whatsoever kind used in connection with the work, and may make use of the same in the completion of the work. The value of such plant shall be determined by three appraisers, one appointed by the Commissioner of Public Works, the second by the contractor, and the third shall be chosen by the two appraisers, already named. In case of the refusal, inability or neglect of the contractor to name an appraiser, such appraiser shall be named by the Judge of the Probate Court of Cook County, State of Illinois. The appraisement shall be in writing, and the value fixed by any two of such appraisers shall be final and conclusive between the parties. When the value is so determined, if there

be anything due the City of Chicago from the contractor by way of damages or otherwise, the amount so found by said appraisers shall be applied to discharge such indebtedness, or shall be held by the city until the amount of damages due to the city shall be ascertained. If nothing is due the city from said contractor, and there is no claim for damages against him, the amount found to be due him, if any, shall be paid to the contractor.

Assignment Prohibited.

The contractor will not be allowed to sublet the whole or any part of the said work, or make any assignment of the moneys to be paid him, without special permission in writing from the Commissioner of Public Works, and the contractor will be required to give his personal attention to the work, but in no case of assignment shall such assignment operate to relieve the contractor or his sureties, either under this contract or under the bond specified in this contract.

Estimates.

In case the material, workmanship and the rate of progress shall be in all respects satisfactory to the Commissioner of Public Works, monthly estimates will be made by him of the value of the work actually constructed and in its permanent place; and each month a voucher for eighty-five per cent of the estimated value of the work done the previous month will issued, and the remaining fifteen per cent to be reserved until the completion and acceptance of the whole work.

Manner of Payment.

....

....

....

Payment of Sub-Contractors and Workers.

Whenever the Commissioner of Public Works shall have reason to believe that the contractor has neglected or failed to pay any sub-contractor, workman, employe or material man, for work performed or material furnished, on or about the work specified in this contract, the Commissioner of Public Works shall order that no further vouchers or estimates be issued and no further payments made upon this contract until the said Commissioner of Public Works shall be satisfied that said sub-contractors, workmen, employes or material men have been fully paid.

Whenever the Commissioner of Public Works shall notify the contractor, either by notice personally served or by leaving a copy thereof at the contractor's place of abode, as shown in this contract, that no further vouchers or estimates will be issued or payments made on this until the said sub-contractors,

workmen, employes or material men have been paid, and the said contractor shall, for the space of ten days, refuse or neglect to pay said sub-contractors, workmen, employes or material men, then it shall become lawful for the City of Chicago, through its proper officers, to apply any money, due or which may become due under this contract, to the payment of the sub-contractors, workmen, employes or material men, this without further notice to the contractor.

Failure of the City of Chicago, through its proper officers, withhold said payments, estimates or vouchers, as specified, or the payment of any or all moneys due under this contract to the contractor, shall not in any way affect the liability of the contractor or his sureties to the City of Chicago, or to any of the said sub-contractors, workmen, employes or material men; upon any bond given in connection with this contract.

Rubbish.

All work, upon completion, must be left entirely clear of rubbish and dirt of every kind and description.

Inspection.

Inspection of the work will be made by the proper authorities, but the right of final acceptance or condemnation of the work will not be waived thereby.

The contractor shall furnish all necessary facilities should it be deemed advisable by the Commissioner of Public works to make an examination of the work already completed. If the work is found defective in any respect, the contractor shall defray the expense of such examination and satisfactory reconstruction. If the work is perfect, such expense will be allowed for by the City of Chicago.

Manner of Carrying on the Work.

The work shall be carried on at such times and in such parts, and in such manner, as the Commissioner of Public Works may direct.

Suspension of the Work.

If for any cause the Commissioner of Public Works finds it necessary or desirable to suspend operations for any considerable length of time, the contractor, on due notification, shall suspend operations until further notice is given him, and he will not be entitled to any damages of any kind or nature whatsoever because of such suspension. He will, however, be allowed further time in the completion of his contract equal to the delay caused by the suspension of the work, as further specified.

Time for Completion.

The contractor shall bid with the express understanding that the work to be performed under these specifications shall

be commenced not later than....days from the time of awarding the contract for same, and shall be completed on or before ...., and that the said time specified for completion of the work is an essential condition of this contract. Provided, however, that if the contractor is delayed by the City of Chicago in the commencement of the work, or in case the work is suspended by order of the city authorities, then the time of such delay or suspension shall be added to the time for completion of this contract.

Miscellaneous.

The right is hereby reserved to the Commissioner of Public Works to finally decide all questions arising as to the proper performance of the work; and in case of improper construction or non-compliance with the contract in any manner, the Commissioner of Public Works may suspend said work at any time or may order the partial or entire recontruction of said work, if improperly done, or may forfeit the contract and relet the same. He may, also, adjust the difference of damages or price, if any, which the contractor failing to properly construct such work, in such cases of default, should pay to the city, according to the just and reasonable interpretation of said contract. In all such matters the decision of the Commissioner of Public Works shall be final between the parties hereto.

Omissions.

Anything omitted in this specification, necessary to fully complete this work in a workmanlike manner, shall be done by the contractor without cost to the city. Anything shown on plans and not mentioned in this specification shall be executed the same as though fully described in this specification, and vice versa.

Incorporation into Contract.

These specifications shall be incorporated in and become a part of the contract.

Rejection of Bids.

The Commissioner of Public Works expressly reserves the right to reject any or all bids.

The undersigned hereby certify that they have read the foregoing specifications and have examined the work to be done and all plans connected therewith, and that the proposal for the work is based on the conditions and requirements embodied therein, and should the contract be awarded to them they agree to execute the work in strict accordance herewith.

Name............................
Residence.....................
Name............................
Residence.....................

Street Flushing Machines.

There are at least five different types of street flushing machines and each machine is patented. To draw up specifications to fit all the flushers was impossible, and after a good deal of worry the scheme was resorted to of having the bidders supply the specifications for their machines. A clause was inserted for a public demonstration of the machines. This demonstration gave us an accurate knowledge of the machines. Another clause stating the results obtained from the competitive tests as well as the price bid, would be taken into consideration in awarding the contract, thus giving us an opportunity of choosing what we thought was the most adaptable machine for our needs. At the time the specifications were drawn, the various flushing machine companies were threatening suit against each other for claims on infringements of patents. The city protected itself against any loss of money by making the successful bidder put up a bond of $10,000 for a period of five years.

SPECIFICATIONS FOR STREET FLUSHING MACHINE.

Instructions to Bidders:

It is the intent of these specifications to receive proposals for street flushing machines suitable for flushing the streets of Chicago in a satisfactory manner.

Water capacity of the tanks to be from 565 to 675 gallons.

Wheels of the machine to be built to accomodate tires of sufficient width to comply with the wide tire ordinance passed by the Common Council of the City of Chicago February 3, 1908, which in part is as follows:

"For any load or burden exceeding 6,000 lbs. but not exceeding 8,000 lbs. the width of the tires shall not be less than 3¼ inches. For any load or burden exceeding 8,000 lbs. but not exceeding 10,000 lbs., the width of the tire shall not be less than 3¾ inches."

Tanks must be built to stand a test of, at least, 100 lbs., per square inch pressure.

Bidders must submit with their proposals complete specifications and cuts, drawings, or photographs of their machines. All machines must be guaranteed in every part against defects due to faulty workmanship or material for a period of one year after the machine is put in service, and any part which breaks or wears shall be replaced without charge.

The contractor to whom the contract is awarded must put up a bond of $10,000.00 for a period of five (5) years to protect the city of Chicago against any lawsuits or damages which may arise for the use of any patented invention or arrangement on the machines.

Bidders shall bid with the understanding that they shall be ready at such time and place as the Commissioner of Public Works may direct to give a public demonstration of the working of their machine, such demonstration to be given free of charge.

Price bid for each machine shall be F. O. B. Chicago.

Bidder shall bid with the understanding that they shall Thirty-nine (39) flushing machines on or before April 1, 1909.

The Commissioner of Public Works reserves the right to reject any or all bids. It is the intent of the City of Chicago to obtain the best flushing machine on the market and the result of the competitive tests as well as the price bid will be taken into consideration in awarding the contract.

Payment to be made from the respective ward funds set aside by the Common Council of the City of Chicago for the use of the respective wards during the year 1908

Transporting Garbage on the Chicago River.

Chicago uses the reduction method for the disposal of its garbage. The reduction plant is located at 39th and Iron streets, which point is on the east bank of the south branch of the Chicago river.

On account of the large area covered by Chicago it is impossible for the garbage wagons to haul directly to the plant. Water transportation being the cheapest form of transportation, loading stations were built at various points along the river.

The city is divided into garbage districts and each district hauls to the nearest loading station. The wagons are provided with removable steel boxes. These boxes are lifted from the running gears by means of a derrick and transferred to barges and then hauled to the plant.

Suitable docks had to be provided for the loading stations and the following specifications describe the typical dock construction.

The city does not own its own garbage fleet, and consequently it was necessary to draw specifications and advertise for a suitable fleet to transport the garbage boxes from the loading stations to the plant. The following specifications were the cause of obtaining a very satisfactory fleet at a nominal daily rental:

SPECIFICATIONS FOR A DOCK TO BE ERECTED ON THE SOUTH END OF OAKLEY AVENUE ON NORTH SIDE OF THE NORTH BRANCH CHICAGO RIVER IN THE CITY OF CHICAGO, COUNTY OF COOK, STATE OF ILLINOIS.

General.

The work hereinafter specified shall consist of the remov-

al of 5,500 cu. yds. (scow), more or less, of material to be dredged at and near street end, and the construction of 74.8 feet, more or less, of new dock along the north side of the north branch Chicago river, being in Section 30, Town 40 North, Range 14 East of 3rd Principal Meridian, across the south end of Oakley Avenue.

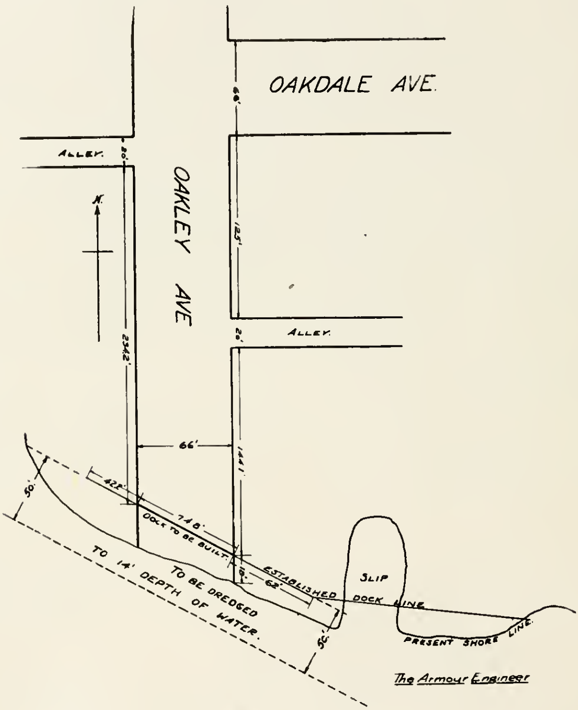

FIG. 1. MAP OF WORK.

The dock shall be built on the line indicated by the engineer in charge or his authorized agent and shall be of the same height as shown on plans.

The prices bid shall include the cost of materials used, and of all labor and use of appliances necessary to turn over to the City of Chicago the completed work, with back filling and

leveling behind the dock neatly and properly done, with all debris of every kind attendant upon the construction of the dock removed from the channel and the dock ready for service.

The contractor will clear away all material necessary to enable him to construct the anchorages, and after having constructed the dock as described will fill up all trenches dug for anchorages, repair street, and fill behind the dock and level up the ground in fair shape to a plane level with the elevation of top of the dock, and remove all debris from the street and deposits in the channel resulting from the construction without separate estimates or payments for such cleaning up or finishing.

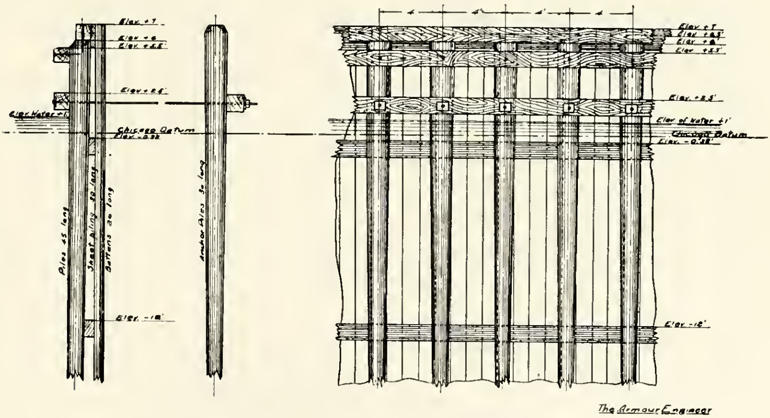

Fig. 2. Elevation of Dock.

The location of the————inch water main is shown on plans. The contractor must protect said water main from any disturbance.

The contractor will be held responsible for any damage done to the sewer.

Dock.

The dock shall consist of white oak piles, capped, sheathed with oak or Oregon fir, sheet piling and pine battens, and anchored back by wrought iron tie rods to anchor piles and back logs, with fender wales attached to channel face of dock.

Old Piles.

All old piles, caps and sheet piling shall be removed, and great care shall be taken that no pile, stub or other obstruction be left in front of the dock line below the water's surface.

Dock or Front Piles.

To be straight, sound, white oak piles, 45 feet long, tapering gradually from point to butt, not less than 8 inches diameter inside the bark at small end and not exceeding 18 inches inside the bark at butt end. All bark shall be stripped from the parts of piles that will project above water line after driving.

The dock piles shall be driven, spaced, not exceeding 4 feet center to center, well aligned.

Anchor Piles.

To be 30 feet long and 18 inches in diameter at the butt. To be driven as shown on plans in a line parallel to the front row and not exceeding 7 feet center to center and at a distance from the front row to allow anchor or tie rods 40 feet long to be used.

Back Logs.

To be placed behind the anchor piles, with the top surface about 2.5 feet above Chicago Datum, in trenches dug by the contractor therefor. The back logs shall be 10x12 inches,

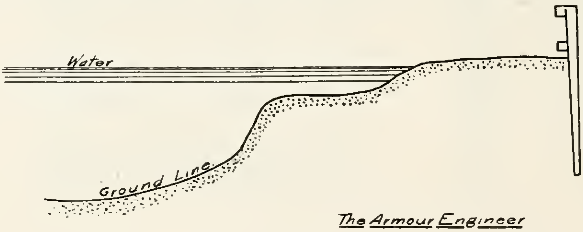

Fig. 3. Section Through River Channel.

Norway pine, or 12x12 inches hemlock, laid flat against the anchor piles which shall be flatted at crossings to give better bearings.

The timbers shall not be less than 16 feet in length each, and old piles cannot be used as back logs. The timbers must be new and of good quality.

Caps.

The front or dock row of piles shall be sawed off in one horizontal plane and capped with one course of sound white oak, at least 12x12 inches, the sticks in the caps to be not less than 22 feet in length and joined together by splice joints machine bolted through the splices with two 14½x1 inch machine bolts at each splice. driven in holes bored 1-16 inch less diameter than bolt. The caps shall be bolted to the heads of the piles by one headed drift bolt 24 inches long and 1½ inches in

diameter, at each pile head crossing. Nailed or spiked to the cap timber in rear and immediately above the upper stringer shall be placed a 3x6 inch white oak or Oregon fir filler overlapping the splices in the cap, making the cap practically 12x15 inches. There shall be four 10x3/8 inch boat spikes, two on each side of splices in cap timber, driven through the filler and into the cap timber, and at intervals not exceeding 4 feet, and at each end of the filler planks there shall be driven two spikes.

Stringers or Timmers

To be three in number to support the dock sheeting. One stringer, 3x12 inches white oak or Oregon fir, shall be placed just below the cap filler and spiked to the piles with two 10-inch steel wire nails or boat spikes at each pile and at each end of plank; one 4x12 inch pine shall be placed thirty-three one-hundreths feet below Chicago City Datum, and one 6x12 inch pine shall be placed 12 feet below Chicago Datum as mud sill.

Sheet Piling.

Each pile to consist of 4-inch white oak or Oregon fir plank 30 feet long, and not less than 10 inches wide, driven close behind the front row of piles. Said plank shall have bearing on the stringers and mud sill and be securely spiked through the cap filler to the 12x12 inch cap timber.

Battens.

The joints or cracks between the sheet plank shall be carefully battened with three inch pine batten, either white, Norway, or long leaf yellow pine, 26 feet long and not less than 10 inches wide, properly nailed on.

Sheeting or batten cracked or split in driving shall not be accepted.

Tie Rods.

To be 40 feet in length, or wrought iron 1¼ inch diameter, placed not exceeding 4 feet apart, passing through each front pile through lower wale and through the back log. The rods shall pass through the front piles at about 2 feet above Chicago City Datum.

The rods shall have button heads not less than twice the diameter of the rods, and shall have their screw ends upset to 1⅝ inch diameter and furnished with standard nuts.

Under both heads and nuts shall be placed wrought iron or steel washers 6 inches square and ½ inch thick. Seats shall be properly prepared to give firm bearing to the washers against piles and back log. Seats for the washers under head of anchor rods on front of lower wale must be countersunk.

Wales.

To be of white oak 12x12 inches, two in number, and placed as shown in plan. They shall be made continuous by

splice joints with the planes of splices vertical. Two ¾ inch bolts 12 inches long, shall be driven through each splice in the wale.

The wales shall be secured to the piles by wrought pointed 1¼ inch drift bolts 22 inches long, with swaged or enlarged heads driven in holes bored 1-16 less in diameter than the bolts, one bolt at each and every pile crossing.

Dredging Dock Channel and Approaches.

The contractor is required to dredge away the material south of the street end and at the east and west approaches thereto for a length of about 240 feet and a width of 50 feet parallel with the dock line securing a depth of 14 feet of water over that area and he is required to tender a price per cubic yard as measured in the scow for the dredging away of about 5,500 cubic yards (scow) of this material and the towing of it to the dumping place in Lake Michigan, that is along a line 1,000 feet from the shore of the lake and between 25th and 39th streets.

SPECIFICATIONS FOR TRANSPORTING GARBAGE ON THE CHICAGO RIVER AND ITS BRANCHES, DEPARTMENT OF PUBLIC WORKS, BUREAU OF STREETS, JUNE 1, 1909, TO MAY 31, 1910, INCLUSIVE.

General.

The work hereinafter specified shall consist of transporting garbage from such places along the Chicago River and its branches as shall be designated by the Commissioner of Public Works to the Chicago Reduction Company's plant at 39th and Iron streets. For the purpose of transporting the garbage as hereinbefore specified the contractor shall furnish one (1) canal steamboat that will have sufficient capacity to carry forty-five (45) regulation garbage wagon boxes and three (3) canal barges that will carry fifty (50) regulation garbage wagon boxes each. The canal boat shall be of sufficient size and capacity to tow the three canal barges. The canal steam boat and three canal barges shall be equipped with canvas covers to cover boats from stem to stern. Canal steam boat and barges to be manned with such crews as will be required for the proper handling of the craft, and to be provided with necessary material, labor, and appliances required for the transportation of garbage. Twenty-four (24) hours to constitute a day's work.

The city of Chicago will collect the garbage and deposit it in boxes 14′x4′x2′6″ which will be laced on the scows or barges, when filled, by the city without expense to the contractor. The city will also unload the boxes at the garbage reduction plant and place them on the canal boat or canal barges after they are emptied without expense to the contractor. The

contractor shall be prepared to furnish the canal steam boat and three canal barges specified above at any and all hours whenever ordered by the Commissioner of Public Works, and the plant shall not be used for any other purpose while the contract is in force.

Should the contractor at any time fail to furnish the above described canal steamboat and three canal barges, the city will hire such plant as may be required for the transportation of the garbage and charge the cost to the contractor.

The price bid for the work shall be per day of twenty-four hours and the time covered by the contract shall extend from June 1, 1909, to May 31, 1910.

The provisions and requirements of these specifications and the contract may be extended for any period beyond May 31, 1910, not exceeding ninety (90) days, at the option of the commissioner of public works, on due notice of such option for such extension by said Commissioner of Public Works. Then and in that event the obligation of said contract continues and is binding in all matters covered by said contract (including the price as bid) as between the city of Chicago and the contractor to the end of said extension of time as fully as the said contract applies on its execution to the period ending May 31, 1910.

Hand Cart for Block System for Street Cleaning.

In many cases the specifications can be materially shortened and the details eliminated by inserting a clause therein similar to the one in cart specifications:

"The cart shall be complete in every detail, except the wheels, and equal in every respect in dimensions, quality of material and workmanship, to a certain sample in the Chicgo Avenue Loading Station in the City of Chicago."

SPECIFICATIONS FOR HAND CART FOR BLOCK SYSTEM OF CLEANING.

Remarks.

Requiring approximately 280 carts, more or less, to be delivered to the various ward yards.

Carts must be delivered within 30 days from the letting of the contract.

Body.

Length 38″, width 24″, depth 24″.

Capacity, approximately ½ cu. yd.

Body to be made of clear wood stock not less than ¾″ dressed and not less than 2 piece sides and end. Body lined throughout with galvanized iron, beveled iron on top edge of body.

Rear end to be hinged at top by rod passing through from side to side. The end door to have slide bolt at bottom.

Two bent draft handles of clear hard wood, bolted thoroughly under the body, extending back to the center and extending beyond the front of the cart, not less than 2 feet 6 inches. These bent draft handles to have cross draft handle at the front.

Axle.

One inch (1″) Norway steel.

Wheels.

The wheels shall be of the best Sarvin type 36″ in diameter with 1½″x5/16″ round head steel tires.

Painting.

The body shall be given two coats of green paint, inside an dout; and the gear two coats of red. All parts to be given one coat of A No. 1 varnish. On the sides the following title shall be lettered in yellow:

CITY OF CHICAGO,
BUREAU OF STREETS.

Requirements.

The cart shall be complete in every detail, except the wheels, and equal in every respect, in dimensions, quality of material, and workmanship, to a certain sample in the Chicago Avenue Loading Station in the City of Chicago.

The dimensions and style of sample cart are shown on plans which are attached hereto and made a part hereof.

Payments for the furnishing of the material called for by these specifications will be paid from the various ward appropriations from account marked 203 C.

Street Brooms.

It is a hard matter to judge the quality of a street broom, and the real test of its worth is a trial for the length of its life in actual use on the street. For this reason a clause was inserted in the specifications for furnishing six samples for inspection and tests.

The Bureau of Streets uses about 1,500 dozen brooms per year; but on account of the fluctuations in price the specifications were drawn to cover a period of three months. The quality of each delivery of brooms is different, and to insure the city against receiving inferior material a clause was inserted allowng the commissioner of public works to terminate the contract at any time. This clause has a tendency to keep the contractor continually on the alert to furnish the best quality of material.

SPECIFICATIONS FOR STREET BROOMS.

Remarks.

Requiring, approximately, 400 dozen, more or less. To be delivered at the various ward yards, located in the thirty-five (35) wards of the city of Chicago, during the term ending

ninety (90) days after signing and delivery of contract.

Brooms must be delivered promptly, and in such quantities, and at such time, and to such places as may be directed by the Commissioner of Public Works.

The quantity of brooms required is an approximate estimate of the amount of material to be furnished. More or less may be required at the contract price for and during said term.

All material is subject to inspection and tests by authorized representatives of the Commissioner of Public Works. When any material is rejected the contractor must immediately remove the same from the place of delivery.

Each bidder must submit at least six (6) standard samples of the brooms he proposes to furnish under his proposal, and in case of the award of the contract to said bidder the samples so submitted shall remain on file in the office of said Commissioner of Public Works and all materials furnished shall be equal to the samples.

At any time during the term of the contract, if, in the judgment of the Commissioner of Public Works, the quality of the brooms is found unsatisfactory and unfit for the use to which they are subjected, the Commissioner of Public Works reserves the right to terminate the contract.

Payments for the furnishing of the material called for by these specifications will be paid from the various ward appropriations made for street and alley cleaning.

Description of Brooms.

The blocks shall be of such a grade of poplar or other wood as will withstand the use they are subjected to without cracking or warping, and shall approximate the following sizes:

Length—Fifteen inches (15″).

Width—Two and seven-eighths inches (2⅞″).

Thickness—One and eleven-sixteenths inches (1 11/16″), one and seven-eighths inches (1⅞″) at each end.

The blocks shall be uniformly drilled with sixty-four (64) holes one-half inch (½″) in diameter, and one (1) hole for the handle one inch (1″) in diameter. The thirty-six (36) outside holes shall be filled with a No. 1 live, stiff and springy Bahia bass, and the inside twenty-eight (28) holes shall be filled with first-class African bass.

The stock shall be six inches (6″) long outside of the face of the block. The knots shall be set with pitch into the one-half (½″) holes and shall be guaranteed not to come out during the life of the broom.

The face of the brush when finished shall be seven and three-quarters inches (7¾″) wide and eighteen and one-half (18½″) long.

It is the intent of these specifications to obtain the best street broom on the market.

Pumping Out Clay Hole.

A survey was made of the clay hole, soundings taken, and an estimate of the number of gallons of water in the hole. This information was not inserted in the specifications. but was given to the bidders on request. A lump sum was bid for doing the work, and no arguments could follow on a disagreement of the number of gallons pumped. This also lessened the expense for the city by not being forced to furnish a man to keep in constant touch with the job.

No chance for dispute. A definite amount to be paid when the work was done and therefore a good specification.

SPECIFICATIONS FOR PUMPING OUT CLAY HOLE AT THE NORTHWEST CORNER OF SOUTH LEAVITT STREET AND WEST FORTY-SEVENTH STREET.

Remarks.

Contractor shall bid a lump sum for pumping the clay hole dry.

No extra price shall be allowed the contractor for building any necessary conduits, aerial pipe or flow line or sewer or any appliance necessary to lead the water to the present city sewers or ditches.

Contractor must bid with the express understanding that the water must be pumped to any of the present serviceable sewers or ditches and so dispose of the water that it will not become a public or a private nuisance to any individual or corporation.

Contractor must submit to the Commissioner of Public Works for approval whatever scheme or plan he intends to use for the disposal of the water before any work is commenced.

Contractor will be held strictly liable for any damage to any property, public or private, which may result from the prosecution of this work.

It is the intent of these specifications to have the clay hole pumped dry and all connecting ditches or pipes blocked so that the hole shall remain dry.

Construction of a Loading Platform.

At the present time one of the big problems of the Bureau of Streets is to find suitable dumps for its street sweepings, miscellaneous waste, and ashes. We have been utilizing abandoned clay holes, but these are being rapidly filled and the length of the hauls are becoming almost prohibitive. Some of the teams are able to make only one load a day, and the cost of removing these materials is increasing daily. We have worked out a very good scheme and with the co-operation of the street car companies have solved the problem. By building loading platforms in different sections of the city, the teams will de-

liver their goods to these platforms, dump directly into cars built for the purpose, and during the night these cars will be hauled to the outskirts of the city and dumped and be brought back to the loading platforms ready for the next day's load.

The following specifications were drawn and the platform built accordingly.

One of the conditions of the specifications was that the length of time required to build the platform would be taken into consideration in awarding the contract. The time limit varied in the bids from 15 to 130 days. The successful bidder completed the platform in 15 days.

SPECIFICATIONS FOR THE CONSTRUCTION OF A WOOD PLATFORM ON FIFTEENTH PLACE, BETWEEN LOOMIS AND THROOP STREETS.

Requiring Approximately 150,000 B. M. of Long Leaf Yellow Pine Lumber.

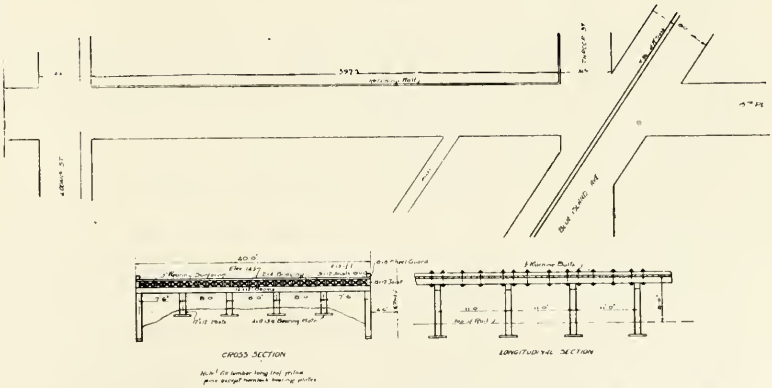

Fig. 4. Cross and Longitudinal Section of Platform with map Showing Location.

Remarks.

Platform shall be approximately five hundred (500) feet long and forty (40) feet wide.

All lumber for the platform shall be of the best quality common long leaf yellow pine lumber, live and sound, free from wind shakes, loose or decayed knots, worm holes or other defects.

Posts supporting cap or floor beam shall be twelve by twelve (12x12) inches, resting on a four by twelve (4x12) inch hemlock plank three (3) feet long.

Caps or floor beams shall be twelve by twelve (12x12) inches and shall be spaced on eleven (11) feet centers. Caps shall have a good, even bearing on each post.

The outer joist shall be eight by twelve (8x12), securely drift bolted with one-half (½) inch bolts to each cap, with butt joints.

All other joists shall be three by twelve (3x12) inches, twelve (12) feet long on eighteen (18) inch centers. The tops of the joist shall form a true plane surface, so that the wearing surface shall not be warped or bulged in any place.

Wearing surface shall be three (3) inches thick, surfaced on bottom, laid close together and spiked with two (2) 60d. nails in each plank to each joist.

The wheel guard shall be eight by eight (8x8) inches, securely anchored with one-half inch (½″) machine bolts extending through the wheel guard, wearing surface and eight by twelve (8x12) joist.

The machine bolt shall have a head and washer on lower face of joist and fastened with a nut and washer on upper face of wheel guard. Bolts shall be placed at two and one-half (2½) foot centers; two by four inch (2x4″) bridging shall be used between joists on eleven foot (11′) centers.

Cross braces shall be two by eight inches (2x8″).

The inclines or approaches to platform shall be built according to plans.

Bids shall be submitted for timber built in place, including all tools and labor and all nails, angles and bolts required per 1,000 feet B. M.

Bidders shall state in their proposals the length of time required to do this work and this shall be taken into consideration in awarding the contract.

4x3″ angles ½″ thick shall be securely fastenedto the inner upper edge of wheel guards to act as a protection to the wheel guards.

THE PURCHASE OF COAL ON SPECIFICATION AND TEST.

BY WARD O. COLLINS.*

In this age of science the purchase of practically all of the materials used by the manufacturer and consumer are made on the basis of a guarantee as to their value, purity, or percentage of the essential constituents. Iron ore, pig iron, steel, etc., are bought and sold almost entirely on their chemical analysis. Large users of fertilizers, oils, paints, acids, etc., buy their raw and finished materials on the merits as indicated by the chemical analysis.

Coal which in many cases comprises one of the biggest items of expense of an institution is in many cases just purchased as "coal." Specifications sometimes are used covering the general grade, as to whether Illinois, Indiana, or West Virginia coal, but seldom is there any provision in the specification to guide in the acceptance or testing. Too many times the coal delivered is accepted, used, and paid for simply because it is black and disappears when thrown into a fire.

The heat value of screenings from the Illinois mines varies in heating value between 10000 and 13000 heat units, and if the better grades of screening such as Hocking Valley and Youghiogheney were included, the range in heating value would vary through a total of 40%.

With the increasing price of coal and the improvements in the methods of testing, the closer supervision of this large and important item is now being watched to a greater extent by the consumers.

Through the efforts and study of the U. S. Geological Survey, the B. T. U. method has its beginning. This system contemplates the purchase of coal on its merits and value to the consumer. The heat value and the percentage of ash are taken into the consideration in arriving at the value of a delivery.

This system is now in use by a great many of the large consumers in the city of Chicago, among their office and manufacturing buildings as well as public and semi public institutions. Twenty five such buildings are under the observation of the writer and are purchasing their fuel on this form contract.

The successful consumation of such testing requires first of all, absolute fairness to both parties morally, as well as the elimination of all possible source of error or corruption. Carefully prepared samples are taken from the deliveries of coal in the various buildings three or four times per week, and on the larger contracts every car of coal is sampled. These sam-

*Class 1902. Vice-President, Gulick-Henderson Co.

ples are brought to the laboratory, the ash, moisture and heat value are determined weekly from these, and the results, together with the delivered value per ton, are reported to the consumer and the dealer as a basis for settlement.

It is of course essential to have a contract between the purchaser and the coal dealer which will provide for the payment of coal on the B. T. U. system. A form of clause used in such a contract is as follows:

> "Coal accepted hereunder shall be paid for monthly on the following basis:—Multiply the B. T. U. (dry coal) by the percentage of moisture (expressed in decimals); subtract this product from the number of B. T. U. (dry coal); multiply the remainder by 2000 and divide this product by the contract guarantee. From this quotient (expressed as dollars and cents) subtract one-half the dry ash percentage (expressed as cents)."

There are other means of arriving at a fair value which, although differing in the wording, are equally fair so long as the basic principles of the quantity of delivered heat and low ash are made imperative in the calculation.

As it will be seen, such a method of purchasing is equally fair to both parties to the contract, and such a contract stimulates the dealer to deliver the kind and quality of coal called for, or otherwise he must suffer a penalty in the form of a reduction in price.

When we speak of the corrupt methods by which coal is sold, by which poor coal is furnished where good is paid for and guaranteed, we cannot lay the entire responsibility to the coal dealer, nor do we wish to be understood as believing there are no honest coal dealers. A great many of the consumers, purchasing agents, crooked engineers and inspectors have contributed by their eagerness to take the bribes and commissions from the coal dealers to make the coal business "an underground operation from the start to finish." The ease with which substitutions can be made, and the difficulty of detection where no honest or efficient testing is done have contributed to corrupt the coal industry.

The close intermingling of politics in many localities is largely responsible for the crooked business, an example of which has recently been partially uncovered by the Merriam Commission of Chicago.

Our recent work for that commission has demonstrated the use and value of systematic purchasing of coal. Lax speci-

fications formerly used in practically all the departments of our city government allowed the delivering of almost anything black for coal. Lack of provision for testing and indifferent attitude toward such matters were all together responsible for the loss of many thousands of dollars annually to the city.

A contract between a private corporation and a coal dealer may be in simple and in few words, as the purchaser does not ordinarily have to protect himself against his own dishonesty. A specification for a city, however, must provide against the dishonesty of its own men as well as to be a protection against the common enemy, the coal dealer. It must compel the city to sample, test and inspect its own coal at stated intervals. It must be explicit in stating many minor points which would be unnecessary with honest supervision or with any real determinations on the city's part to enforce delivery. Such specifications must provide a protection for the honest coal man, for the coal man who does not care to purchase immunity from persecution. It must provide a means by which he will be repaid for honest deliveries, as well as to penalize him for poor deliveries.

On account of the many traps and pitfalls connected with the sale of coal to a corrupt city there is little or no competition for such business. In cities as well as public institutions where the B. T. U. system has been honestly and efficiently applied, and where the testers have been honestly and efficiently backed up in their work, the savings have been enormous, to say nothing of the satisfaction which comes with knowing that no imposition or substitution has been allowed.

Private corporations and large consumers have been generally favorable to the B. T. U. system where it has been honestly tried, though of course there have been failures due to dishonest tests and lack of knowledge; but with the improvement of the apparatus and systematizing of the details of handling the system, the same will certainly continue to increase in its popularity and usefulness to both the private as well as the public corporations.

FORMS OF NOZZLES FOR IMPULSE WATER WHEELS.

BY A. H. ANDERSON, M. E.*

The principal methods of keeping constant the speed of impulse water wheels are:

(1) Varying the number of jets in action;

(2) Varying the quantity of water in the jet or jets which impinges upon the wheel;

(3) Varying the size of the jet.

Case 1. The nozzles may be distributed about the periphery of the wheel at equal intervals, each nozzle being controlled by its own shut-off valve, and all being supplied from the same pressure main. When the wheel is running at its maximum capacity all of the nozzles would be discharging

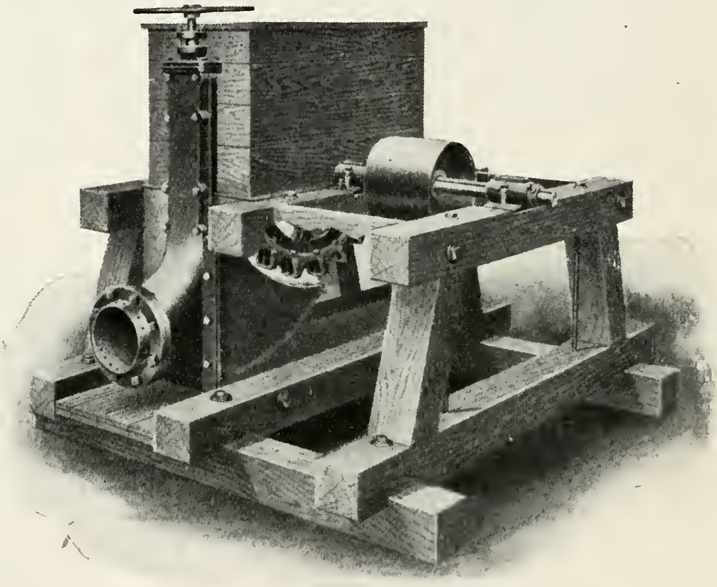

FIG. 1.

water; should the load on the wheel drop off somewhat, its speed would increase and it would be necessary to partially or entirely close one of the nozzles thus bringing the speed back to the normal point. Should the load further decrease another of the nozzles would have to be partially or entirely closed; and so on for still further diminutions of load. If now the load should increase the speed of the wheel would fall and it would be necessary to open one or more nozzles in order to restore the speed.

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This method is adaptable only to hand regulation. When it is desired to use an automatic governor in connection with a number of nozzles the construction would be as shown in Fig. 1. Here it will be noted the nozzles are grouped, being formed in one casting, all of them opening into one common pressure chamber. A flat plate connected with the hand wheel is arranged so that it may cover the end of the nozzles opening into the pressure chamber and thus vary the number of nozzles discharging water. A governor may be attached to the hand wheel stem for automatic operation.

Case 2. In this method only one nozzle is used which is hinged as shown in Fig. 2, so the jet of water may strike the

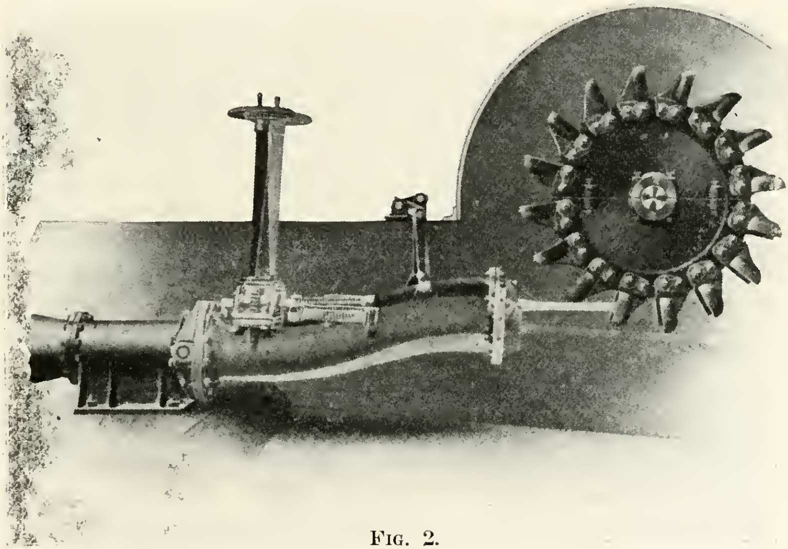

Fig. 2.

buckets full or the jet may be deflected, a part of the water not striking the buckets at all. Of course when the entire jet impinges on the buckets the capacity of the wheel at a certain speed is a maximum. Should the load drop off, the governor would deflect the nozzle until the speed is brought back to normal.

A variation of case two is to construct the wheel in halves, the line of partition being perpendicular to the shaft. By means of the governor the halves may be held up close to each other forming a perfect wheel or they may be separated to a greater or less degree. One or more jets may act upon the

wheel and for maximum capacity the halves would be drawn up close to each other. Should the load now decrease the governor would act to separate the halves, allowing a portion of the jet to escape between them, until the speed of the wheel had been reduced to normal.

Case 3. Varying the size of the jet is best done with what is called the needle nozzle. In this nozzle there is a core placed so that it may be moved axially to vary the amount of annular opening through which the water may pass. The core and inside of the nozzle are finished with great care and shaped in conformity with the stream lines and as a result the coefficient is very high, rarely going below 99%. It has the further

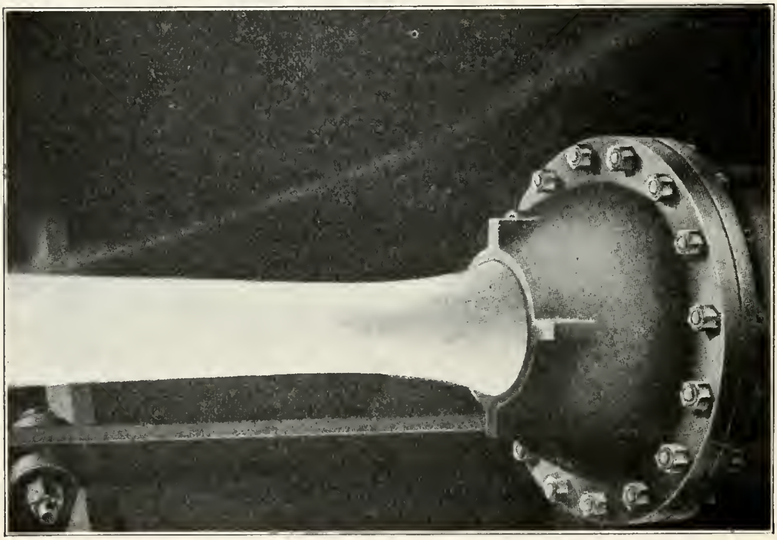

FIG. 3.

advantage that its coefficient is practically constant over a large range of capacities. In Fig. 3 the shadow of the core tip may be seen through the jet of water. The stem of the core may be attached to a hand wheel for ordinary hand regulation or to a governor for automatic regulation.

The combination of a deflecting nozzle and needle nozzle is an effective one. The deflecting nozzle is wasteful of water while the needle nozzle is sluggish. In such a combination a decrease in load on the wheel will cause the nozzle to be suddenly deflected by its governor. Simultaneously the needle nozzle will be actuated by another governor tending to grad-

ually close the core and decrease the flow. The governor then raises the nozzle to accommodate the decreased flow of water and the nozzle is brought back to the position of greater efficiency.

Fig. 4 shows a set of relief valves. These consist of a number of disks held to their seats by springs whose strength only slightly exceeds the normal water pressure. The set is

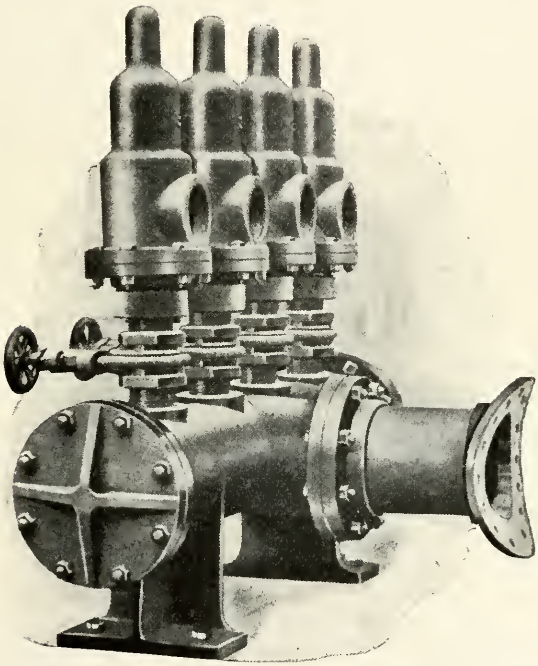

FIG. 4.

tapped into the main pressure line near the nozzle, by means of the saddle flange. If the nozzle should be cut off suddenly the excess pressure caused will lift the valves and the water will pass out of the four openings at the base of the hoods, thus avoiding the danger of any damage from water hammer. [The illustrations are used by permission of the Pelton Water Wheel Co.]

INVESTIGATION OF THE ESSENTIAL CONSTITUENT OF TURKEY-RED OIL, AND ITS DERIVATIVES.

BY M. WOLDENBERG, B. S., Ph. D.*

Turkey-red oil is won through the action of concentrated sulphuric acid on castor oil. The resulting product, which contains an excess of sulphuric acid, is dissolved in ammonia—or soda-solution.

Turkey-red oil is a very complicated mixture of derivatives of ricinoleic acid ($C_{18}H_{34}O_3$). It contains in the form of ammonium salts—that is, sodium salts, free ricinoleic acid, the sulphuric-acid-ester of these sodium or ammonium salts[1], and the sulphuric-acid-ester of castor oil; perhaps also a mixed di-ricinoleic-acid-sulphuric-acid glyceride[2], sulphuric-acid-ester of dioxystearic acid,[3] ricinoleic-acid-anhydride,[4] polyricinoleic-acids,[5] and other complicated compounds.

The reaction of sulphuric acid on ricinoleic acid or its glyceride has been investigated innumerable times. Regardless of this fact, however, the course of the reaction, taken as a function of time, is still very unclear; the most important product of this reaction, the sulphuric-acid-ester, has never been thoroughly investigated (not even isolated in its pure form), and has never been characterized through its derivatives.

The following research was undertaken primarily with the object of joining the numerous bits of information on this subject, and filling in such gaps as may present themselves, so as to leave the problem conclusively solved, if possible. The reaction of grammolecular equivalents of sulphuric acid and ricinoleic acid was investigated first, then the reaction between sulphuric acid and the methyl ester of ricinoleic acid was studied. [In place of the glyceride (castor oil), the methyl ester of ricinoleic acid was used, as this reduces difficulties to a minimum, and at the same time gives a similar reaction to that of the glyceride.] Inasmuch as the isolating of the sulphuric-acid-ester of the ricinoleic acid from the other products of this reaction did not seem worth the while, we worked out another method for its direct production. This new method was carried over to saturated and unsaturated derivatives of

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*Class 1906, Zürich, Chemisches Universitäts Laboratorium. Woldenberg and Schaar, Chemical Engineers, Chicago.

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1 Benedikt and Ulzer, Monatshefte für Chenire, 8.208 (1887). Scheurer-Kestner, Bull. de la soc. ind. de Mulhouse, 1891. See also, Wilson, Jour. soc. chem. ind. (1891), 26.

2 Bogajewski, Chem. Centrallbatt. 1897, II, 335. See also, Liechti, Berichte d. Deut. Chem. Gesell. 16.2453 (1883).

3 Juillard, Bull. soc. chim. 1891, p. 6; 1894, p. 280. Juillard, Bull. soc. ind. Mulhouse, 1892, p. 415.

4 Juillard, loc. cit.

5 Scheurer-Kestner, loc. cit.; Juillard, loc. cit.

ricinoleic acid, so that in this way, derivatives of the sulphuric-acid-ester of ricinoleic acid could be won, and then material for direct comparison was obtained.

Following is an outline of experiments undertaken:

The influence of sulphuric acid on ricinoleic acid and on its methylester.

The influence of chlorsulfonic acid on ricinoleic acid, and on its methylester.

[The preparation and characterization of the sulphuric acid ester of ricinoleic acid.]

The preparation of ricinstearolacid and its sulphuric acid ester.

The synthesis of the sulphuric acid ester of dibrom-ricinoleic acid.

The direct conversion of ricinoleic-acid-methyl-ester into 12-oxystearic-acid-methyl-ester.

The preparation of 12-oxystearic acid, and the conversion into its sulphuric-acid-ester.

The preparation of polymerisation products of ricinoleic acid.

Sulphuric acid reacts violently with ricinoleic acid; at room temperature there follows an instantaneous black-coloring under oxidation of the organic compound, and generation of sulphur-dioxide. It is necessary, therefore, to mix the components of the reaction under cooling to at least 0°C. Even with this precaution, a temperature increase is noticeable after the addition of each drop of sulphuric acid.

Even the first series of tests showed somewhat surprising results—namely: that the esterification was much slower than expected, on judging by sight.

Numerous checks run on this series always gave similar results—namely: that, as was analytically determined through the acid number, and the Hübl-number of the reaction-mixture, only small amounts of the ricinoleic-acid-sulphuric-acid-ester were formed, and that also in the first few hours of the reaction there followed no addition on the double-bond under formation of dioxystearic-monosulphuric-acid-ester.

The reaction mixture is, regardless of the above observations, a wholly homogeneous, clear liquid, in which neither ricinoleic acid or sulphuric acid are directly detectable. This phenomenon is explainable through the assumption that, first, an addition of sulphuric acid takes place, not on the double bond, but on the hydroxy-group of the ricinoleic acid or rather on its hydrogen atom, and that a salt is formed, which by virtue of its nature is unstable and decomposes when titrated:

$$C_{17}H_{32}\!-\!\left\{\begin{array}{l}-OH.H_2SO_4\\ -COOH\end{array}\right.$$

Other observations show also, that the hydroxy-group of the ricinoleic acid possesses a weak basic character. The assumption of a primary salt-building is in itself not arbitrary in the esterification of alcohols through sulphuric acid.

Hautzsch[1] found that methylalcohol dissolved in absolute sulphuric acid (independent of the concentration of the solution) showed ⅔ its normal value by the kryoscopical determination of its molecular weight. This proves, according to Hautzsch, that there appears to be a primary addition, and then there follows under splitting-off of water, the formation of the ester.

Similarly in the case of ricinoleic acid, the reaction resolves itself principally into a splitting-off of water, and an ester-building; the addition reaction goes on slower. However, if we leave the reaction-mixture stand until the first reaction seems to have quantitively proceeded (determined by running an acid-number), then the Hübl-number of the mixture shows that the addition has also taken place to a decidedly noticeable degree.

From the decrease of the Hübl-number (= 15, 6) it may be calculated (see Table I) that the reaction-mixture contains approximately 18% of a saturated acid[2] [dioxystearicacid (CH_3 $[CH_2]_5$ CHOH $[CH_2]_2$ CHOH $[CH_2]_7$ COOH)]; it follows, therefore, that about ¼ of the quantity of ricinoleic acid reacted in this sense. As the dioxystearicacid does not exist free here, but in the form of its mono- and perhaps also of its di-sulphuric-acid-ester, therefore the observed decrease in the acid-number is not due exclusively to the esterification. The acid-number determined after the reaction of the mixture for 115 hours coincides with that calculated for a quantitative ester-formation.

The sulphuric-acid consuming by reaction, determined through the Hübl-number, shows that even after such a long space of time the formation of ester is not complete.

Beside the two reactions spoken of, there still remains a third to be considered—namely: that of the formation of anhydrides of ricinoleic acid (under the removal of water); this would also tend to decrease the acid-number. It is readily seen that the analytical results are not sufficiently decisive to give an entirely clear picture of the course of the reaction. Nevertheless, these results suffice to show the investigator that the reaction is indeed complicated, and that this method for the preparation of ricinoleic-sulphuric-acid-ester is not suitable.

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1 Zeitsch. für physik. Chem., 61.267 (1907).

2 Grün Berichte d. deutsche chem. Gesell. 39.4400.

TABLE I.

Time	Acid Number	Hübl-number	Free Sulphuric Acid Per cent	Sulphuric Acid (not free) Out of the Difference Per cent	Free Ricinoleic Acid Per cent
Mixture of Free Ricinoleic Acid and Sulphuric Acid, 1:1	425,0	64,04	24,62	....	75,38
After 2 hours	365,55	66,72	15,99	8.63	5.93
After 18 hours	335,20	58,44	....	....	...
After 27 hours	327,20	59,31	18,52	6,10	7,41
After 42 hours	314,84	54,89	20,73	3,89	0
After 50 hours	311.80	54,98	21,03	3,59	0
After 68 hours	306,23	51,53	14,10	10,52	0
After 74 hours	303,78	51,77	....	....	...
After 80 hours	302,78	50,54	15,75	8,87	0
After 98 hours	300,13	49,59	....	....	...
After 115 hours	279,79	48,38	18,36	6,26	0

Still more complicated are the conditions in the reaction of ricinoleic-acid-methyl-ester with sulphuric acid, because in this case there occurs on the one hand a decrease in the acidity of the mixture through esterification of the alcoholic-hydroxy-group (and through addition of sulphuric acid), and on the other hand there is also the possibility of an increase in the acidity due to saponification, in that the primarily formed compound (CH_3 . OSO_3H) decomposes itself. However, this series of tests show (see Table II) a continual decrease of the acid-number as also the Hübl-number; consequently a simultaneous progress of the substitution and additional reaction. The reaction mixture after about 118 hours contains 14% saturated acid (calculated as ester, from the decrease in the Hübl-number). Therefore, about 18.5% of the ricinoleic-acid-ester originally used, added sulphuric acid. It follows that a new method is necessary for the production of ricinoleic-sulphuric-acid-ester. Out of a great number of tests, it developed that the most satisfactory method is that which employs chlorsulfonicacid in a neutral medium. After trying pyridine, chloroform, carbon-tetrachloride and several other solvents as neutral mediums, ether was tried, and found to give the best results.

The pure ester [CH_3 $(CH_2)_5$ $CHOSO_3H$. $CH_2CH = CH$ $(CH_2)_7$ $COOH$] obtained in the above described manner, was investigated and the results obtained coincided with those sev-

eral times reported as properties of the purely technical product. The compound is very stable in alkaline solution, and to a certain degree in cold water, but is unstable in acid solution. By boiling a diluted solution of the ester, there appeared to be a quantitative splitting off of sulphuric acid.

TABLE II.

Time	Acid Number	Hübl-number	Free Sulphuric Acid Per cent	Sulphuric Acid (not free) Out of the Difference Per cent
Mixture of Free Ricinoleicacidmethylester and Free Sulphuric Acid, 1:1	273,6	6,86	23,9	....
After 2 hours	250,02	57,90	22,89	1,01
After 8 hours	245,69	52,83	19,66	4,24
After 22 hours	233,99	57,46	....	....
After 31 hours	231,47	57,91	14,41	9,48
After 46 hours	225,62	50,71	10,73	13,17
After 55 hours	225,63	53,90	12,13	11,73
After 70 hours	225,92	51,20	13,51	10,38
After 79 hours	227,52	53,24	....	....
After 94 hours	232,51	49,09	17,02	6,88
After 103 hours	231,08	48,28	....	....
After 118 hours	236,83	50,36	21,78	2,12

Up to the present it has been overlooked that by this process, the ricinoleic acid is not totally regenerated. A large portion of the acid converts itself into an anhydride of ricinoleic acid. As yet, it is not known decisively which anhydride is formed (perhaps several). The simplest suggestions follow:

I

$$CH_3 . (CH_2)_5 \begin{cases} CH . CH_2 . CH = CH\ (CH_2)_7CO \\ \quad \Big| \qquad\qquad\qquad\qquad\qquad\quad \Big| \\ \quad \text{———————————————} O \end{cases}$$

(Lactone of ricinoleic acid)

II

$$\begin{array}{l} CH_3 . (CH_2)_5 \\ \quad | \\ \quad CH.OCO(CH_2)_7CH = CH.CH_2.CHOH.(CH_2)_5.CH_3 \\ \quad | \\ \quad CH_2.CH = CH.(CH_2)_7.COOH \end{array}$$

(Ricinoleicacid-ester of ricinoleic acid)

It is also possible that a lactide of ricinoleic acid could be formed. This point requires special investigation, however, and time does not permit of its treatment in this work.[1]

It was found impossible to prepare the sulphuric-acid-ester of ricinoleic-acid-methyl-ester by a direct method. This was due to the fact that methylester is partially saponified regardless of all precautions. In this case the resulting product is also principally the ester of the free acid. It was characterized in the form of its barium salt.

The reaction of chlorsulfonic acid with the other derivatives of ricinoleic acid were carried out without many difficulties.

The greatest difficulties were encountered while working with the original compounds. This is especially true of the 12-oxystearicacid, which was finally prepared by way of catalytic reduction of the ricinoleic-acid-methyl-ester, and saponification of the oxystearicacid-methyl-ester thus obtained. These compounds are very similar to the ricinoleic-acid-sulphuric-acid-ester in their characteristic properties.

In the case of dibromricinoleic acid the tendency to form an anhydride through the splitting off of water, or rather sulphuric acid, was likewise observed; in fact, the property of "closing of the ring" (or inner-ester formation) is more defined with this compound than even with ricinoleic acid itself. It was necessary to prove this very point with a saturated derivative of ricinolcic acid, which showed that the condensation is independent of the configuration of the ricinoleic acid.

The sulphuric acid ester of the dibromide is more unstable than the rest of the analogous compounds, but this characteristic may be accounted for by the unstableness of the bromine-atom, which fact was already demonstrated in the case of ricinoleicacid-dibromide.

The 12-oxystearic-acid-sulphuric-acid-ester, the other saturated compound, is more stable than the ricinoleic-acid derivative, which fact is in accordance to expectations, as this compound possesses less ability to form intermolecular reactions.

The derivative of the stearic acid proved itself to be quite stable. It occupies about the middle position, as regards to stableness, between the ester of ricinoleic acid, and that of 12-oxystearic acid.

The numerous observations of the formation of anhydrides or inner-esters created a desire for finding a method of preparing these compounds directly. This desire was made keener when it was learned that the closing of "molecular-

[1] From the report of an investigation still in progress under A. I. Grün and N. Wetterkamp, it has been determined that first the compound II is formed, and then after long heating of the ester in water the lactide of ricinoleic acid is formed. See Zeits, Farben-Industrie, 7, Heft 22 (1908).

rings," such as the formation of a 1, 12-lactone or -lactide were heretofore never ascertained. The influence of phosphorpentoxide upon ricinoleic acid was investigated with this end in view. These experiments led to peculiar results—namely: that polymerisation-products were formed, and not anhydrides as was expected. Two distinctly different polymerised ricinoleic acids were isolated. One compound is, as might be concluded from its properties, a product of the union of a lesser number of molecules of ricinoleic acid $(C_{18}H_{34}O_3)_2$ (?), which is soluble in ether, and can be reconverted into ricinoleic acid. The other compound shows no physical properties of a fatty-acid but has a more rubber-like consistency, is insoluble in all organic solvents, and does not allow itself to be reconverted (at least not under the same conditions as the first polymerisation-product) into riciniolcic acid.

THE GENERAL EXPRESSIONS FOR ALTERNATING CURRENT CIRCUITS.

BY G. E. MARSH.*

The complex variable provides the most universally applicable means for the numerical computation of alternating current quantities. In addition to the unequalled accuracy of the method there is usually a saving of time which in some instances may be of importance. For complicated networks the method of the complex variable stands alone in the matter of utility, though for simple circuits its advantages are not so pronounced, and unless the question of accuracy in results is foremost, its employment becomes a matter of personal choice.

An examination of the works on alternating current theory fails to reveal more than an occasional and simple application of the complex variable method to circuits in general. It is interesting, therefore, to develop the equations that apply to the complex alternating current circuit and constitute the variable current counterparts of those so well known in elementary continuous current theory. Strictly speaking, the latter are but special forms of the first mentioned equations.

The equations herein derived are perfectly general and are applicable with proper interpretation to all circuits regardless of the distribution of the impedance and of its value. They apply in all generality to circuits having any combination of resistances, inductances, and capacities. Any mutual induction which may be present in the circuits is considered negligible. The numbered expressions are available for purposes of numeral computation.

The symbols have the following significance:

E_0 = E. M. F. impressed on the line or network,

I_0 = Total current taken by line.

r = Resistance expressed in ohms

x = reactance expressed in ohms,

$$x = \left(2\pi fL - \frac{1}{2\pi fc}\right),$$

E_p = Voltage drop over the pth impedance.

The quantities known as the conductance and the susceptance, designated by g and b, respectively, are determined by the equations

$$g = \frac{r}{r^2 + x^2},$$

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$$b = \frac{x}{r^2 + x^2}.$$

The inductance, capacity and frequency, represented by the letters L, C and f are expressed in henrys, farads and cycles per second respectively. The subscript p is used to indicate the expression for the general term of the type under consideration.

The Case of M Impedances in Series.

If we make use of the usual notation of the complex variable as adapted to alternating current considerations, we have at once.

$$\left.\begin{aligned} E_1 &= (r_1 + jx_1)I_o, \\ E_2 &= (r_2 + jx_2)I_o, \\ &\dots\dots\dots\dots\dots \\ E_p &= (r_p + jx_p)I_o, \\ &\dots\dots\dots\dots\dots \\ E_m &= (r_m + jx_m)I_o, \end{aligned}\right\} \quad (a)$$

and vectorially,

$$E_o = E_1 + E_2 + \dots E_p + \dots E_m. \quad (b)$$

From Equations (a) and (b) we obtain directly

$$\begin{aligned} E_o &= I_o[\,(r_1 + r_2 + \dots r_m) + j(x_1 + x_2 + \dots x_m)\,], \\ &= I_o(\Sigma r + j\Sigma x) \end{aligned} \quad (c)$$

It is to be understood that the symbol Σ stands for the operation of taking the sum of the m resistances in the first instance and of the m reactances in the second; that is, $\Sigma r = (r_1 + r_2 + \dots . r_m)$. The numerical value of E_o is given by the square root of the sum of the squares of the components of the complex equation (c). Accordingly,

$$E_o = I_o\sqrt{[\,(\Sigma r)^2 + (\Sigma x)^2\,]} \quad (1)$$

From equations (a) and (c) we may obtain an expression for the drop over the pth impedance, which is

$$E_p = \frac{E_o(r_p + jx_p)}{\Sigma r + j\Sigma x},$$

and which gives on separating into the two components and taking the square root of the sum of their squares, the expression suitable for the purpose of computation:

$$E_p = \frac{E_o \sqrt{[(r_p^2 + x_p^2)]}}{\sqrt{[(\Sigma r)^2 + (\Sigma x)^2]}}. \qquad (2)$$

The angle of phase difference between the drop over the pth impedance and the current is given by

$$\tan \theta_p = \frac{x_p}{r_p}, \qquad (3)$$

and similarly for the phase angle between E_o and I_o,

$$\tan \theta_o = \frac{\Sigma x}{\Sigma r}. \qquad (4)$$

The Case of M Impedances in parallel.

In the nomenclature of the complex quantity as applied to parallel or multiple alternating current circuits, we have as the expressions for the current in the several branches,

$$\left.\begin{array}{l} I_1 = (g_1 - jb_1)E_o \\ I_2 = (g_2 - jb_2)E_o \\ \dots\dots\dots\dots\dots\dots \\ I_p = (g_p - jb_p)E, \\ \dots\dots\dots\dots\dots\dots \\ I_m = (g_m - jb_m)E, \end{array}\right\} \qquad (d)$$

and vectorially

$$I_o = I_1 + I_2 + \dots I_p + \dots I_m. \qquad (e)$$

Combining Equations (d) and (e) there results

$$I_o = E_o(\Sigma g - j\Sigma b),$$

and hence

$$I_o = E_o \sqrt{[(\Sigma g)^2 + (\Sigma b)^2]} \qquad (5)$$

Similarly, the expression for the current in the pth branch is given by

$$I_p = \frac{I_o(g_p - jb_p)}{\Sigma g - j\Sigma b},$$

and

$$=\frac{I_o}{(\Sigma g)^2+(\Sigma b)^2}\sqrt{[(g_p\Sigma g+b_p\Sigma b)^2+(b_p\Sigma g-g_p\Sigma b)^2]} \quad (6)$$

The value of the phase angle in the case of the pth impedance, that is, the angle between E_o and I_p, and in the case of the angle between E_o and I_n are given respectively by

$$\tan\theta_p=\frac{x_p}{r_p}, \quad (7)$$

$$\tan\theta_o=\frac{\Sigma b}{\Sigma g} \quad (8)$$

The Case of Series-Parallel Circuits.

Let there be a groups of divided circuits in series, and let the number of paths in parallel in the several groups be n_1, n_2, . . . n_a, respectively. Furthermore, let ${}_1i_1$, ${}_2i_1$, . . . ${}_{n_1}i_1$; ${}_1i_2$, ${}_2i_2$, . . . ${}_{n_2}i_2$; ${}_1i_p$, ${}_2i_p$, . . . ${}_{np}i_p$, be the currents in the branches of the first, second and pth groups. If the drops over these same groups be designated by E_1, E_2, . . . E_p, then we may write at once

$$\left.\begin{array}{l}
E_1=\dfrac{{}_1\dot{i}_1}{{}_1g_1-j_1b_1}=\dfrac{{}_2\dot{i}_1}{{}_2g_1-j_2b_1}=\ldots\ldots=\dfrac{{}_{n_1}\dot{i}_1}{{}_{n_1}g_1-j_{n_1}b_1},\\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\
E_p=\dfrac{{}_1\dot{i}_p}{{}_1g_p-j_1b_p}=\dfrac{{}_2\dot{i}_p}{{}_2g_p-j_2b_p}=\ldots\ldots=\dfrac{{}_{np}\dot{i}_p}{{}_{np}g_p-j_{np}b_p},
\end{array}\right\}(f)$$

Now the total current is given by

$$\left.\begin{array}{l}
I_o={}_1i_1+{}_2i_1+\ldots{}_{n_1}i_1,\\
\quad={}_1i_2+{}_2i_2+\ldots{}_{n_2}i_2,\\
\quad\cdots\cdots\cdots\cdots\cdots\cdots\\
\quad={}_1i_p+{}_2i_p+\ldots{}_{np}i_p.
\end{array}\right\}\quad(g)$$

The elimination of the individual currents through a combination of Equations (f) and (g) gives

$$\begin{aligned}
I_o&=E_1[({}_1g_1-j_1b_1)+({}_2g_1-j_2b_1)+\ldots({}_{n_1}g_1-j_{n_1}b_1)],\\
&=E_p[({}_1g_p-j_1b_p)+({}_2g_p-j_2b_p)+\ldots({}_{np}g_p-j_{np}b_p)].
\end{aligned}$$

From the last equation, selecting it as a typical one, we have

$$I_o = E_p[\sum_1^{np} g - j\sum_1^{np} b],$$

and consequently,

$$I_o = E_p\sqrt{[(\sum_1^{np} g)^2 + (\sum_1^{np} b)^2]} \tag{9}$$

The angle of lag is given by

$$\tan\theta_p = \frac{\sum_1^{np} b}{\sum_1^{np} g}. \tag{10}$$

Equation (9) enables the total or line current to be computed when the electrical constants and voltage drop for any one group are known. Equation (10) gives the angle of phase difference between the drop over the group and the line current.

The impressed voltage is given by the vectorial sum of the votage drops; that is, we have

$$E_o = E_1 + E_2 + \ldots + E_a$$

$$= I_o[\frac{1}{\sum_1^{n_1} g_1 - j\sum_1^{n_1} b_1} + \frac{1}{\sum_1^{n_2} g_2 - j\sum_1^{n_2} b_2} + \ldots \frac{1}{\sum_1^{n_a} g_a - j\sum_1^{n_a} b_a}]$$

To simplify the following expressions let the quantities $\sum_1^{n_1} g$, $\sum_1^{n_1} b$, etc., be replaced by G_1, B_1, etc. We then have

$$E_o = I_o[\ (\frac{G_1}{G_1^2+B_1^2} + \frac{G_2}{G_2^2+B_2^2} + \ldots \frac{G_a}{G_a^2+B_a^2})$$

$$+ j\left(\frac{B_1}{G_1^2+B_1^2} + \frac{B_2}{G_2^2+B_2^2} + \ldots \frac{B_a}{G_a^2+B_a^2}\right)],$$

and if in this last equation primed letters be written for the corresponding fractions, there results

$$E_o = I_o[(G'_1 + G'_2 + \ldots G'_a) + j(B'_1 + B'_2 + \ldots B'_a)]$$

or

$$E_o = I_o[\sum_1^a G' + j\sum_1^a B']$$

and

$$E_o = I_o\sqrt{[(\sum_1^a G')^2 + (\sum_1^a B')^2]} \qquad (11)$$

If the line current is unknown then the impressed voltage, or any of the drops, as that over the pth group, can be determined by means of equation (12) which is a combination of Equations (9) and (11), the current having been eliminated.

$$E_o = E_p\sqrt{[(\sum_1^{np} g)^2 + (\sum_1^{np} b)^2]} \cdot \sqrt{[(\sum_1^a G')^2 + (\sum_1^a B')^2]} \quad (12)$$

The angle of lag between the terminal voltage and the total current is clearly given by

$$\tan \theta_o = \frac{\sum_1^a B'}{\sum_1^a G'}. \qquad (13)$$

The determination of the current in any particular branch, the drop over any group, or the lag angle in any member of a group can be accomplished through the application of the results obtained in the first two cases considered.

CAR VENTILATION.

BY D. I. COOK.*

The question of car ventilation is one of the utmost importance and one in which the public as a class is deeply interested. The tendency of the times is toward improvement in matters of sanitation and hygiene, and the value of pure air as a factor in the maintenance of health cannot be overestimated. The medical profession is advocating improvements along the lines of ventilation and has classified various diseases under the heading of "impure air diseases."

The provision for venilation of cars and passenger conveyances is in general extremely inadequate. In most instances the monitor deck sash of cars affords the only means for the introduction of fresh air aside from leakage around doors and windows. During such seasons as it is necessary to operate the cars with the doors and windows closed, the incoming air introduced at the roof level when the car is in motion tends to chill the passengers and produce dangerous and disagreeable drafts of air. At best the deck sash provides only a means of escape of the heated air from the car and the ingress of side currents of air induced either by the movement of the car or the varying wind pressures on the exterior. The deck sash does not ventilate, and when the sashes on both sides are opened, the incoming air is blown through and out on the opposite side, without ventilating the car interior to any perceptible degree.

The necessity for improvement of existing conditions has been recognized for many years, and many schemes, both ingenious and novel, have been advocated or suggested. One of the first attempts to provide ventilation for electric cars to any large extent was that devised and at present in use on the cars of the Detroit City Railway. The combination heating and ventilating system in use in that city on the surface cas consists of a stove placed in the front vestibule and having a connection with the outer casing surrounding the firebox, this terminating in a rectangular duct opening into the car interior at the upper deck level and projecting into the car interior. The heated air being introduced into the car at the forward end is gradually diffused throughout the length of the car, and the frequent opening and closing of the car doors is depended upon to assist in and produce a circulation of air through the car.

In the City of Chicago the question of car ventilation has been receiving serious consideration for the past few years. The advent of the P. A. Y. E. car, which has been adopted as standard in that city, has made more apparent the absolute necessity for some improvement over existing conditions as

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*Secretary and Chief Engineer, Vacuum Car Ventilating Co.

regards the matter of ventilation. Under normal operation this type of car is running with the front door closed except when the car is standing still to take on or let off passengers.

Before the introduction of the vestibule type of car there were certain periods of time during which the front and rear doors of the car were open, thus permitting a flow of air through the car when in motion, which partially cleared the air, as well as materially reducing the temperature inside. Under present conditions, however, the front vestibule of the car acts as an air lock and the deck sash ventilation has proved itself inadequate to meet the standards of ventilation as laid down by the authorities. The ordinances relating to the safety

Fig. 1. Inside of Car Equipped with Mechanical Ventilators.

and comfort of passengers for many years past have provided that the cars shall be properly ventilated, no definite standard, however, being set. At the present time an ordinance is before the city council, which provides for the introduction of 350 cubic feet of fresh air per passenger per hour. The minimum requirement based on the carrying capacity of the car is not less than 28,000 cubic feet of fresh air per hour per car. The draft of this ordinance provides that the the air should be introduced at or near the floor line, and that the foul or viti-

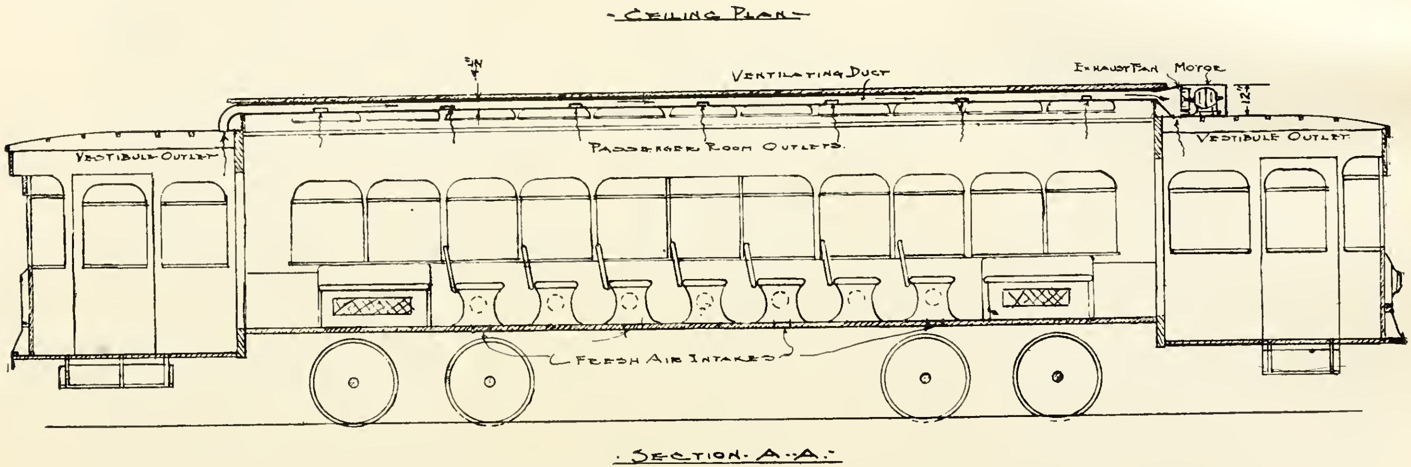

Fig. 2. Sectional Elevation of Car Equipped with Mechanical

ated air be exhausted at the upper or roof level of the car.

During the past two years a number of the various car ventilating devices on the market have been placed on cars and operated in the city of Chicago under conditions of ordinary service. Certain of these systems belong to the class of so-called natural systems, an application of the aspirator principle being made use of in one form or another. Certain systems were tested, which in themselves have been used in years past on steam railroad service. The conditions of operation of ordinary city surface cars presents certain features differing materially from those met with in the case of steam railroad operation, where the cars are operated at a comparatively high speed, with infrequent stops. In ordinary city

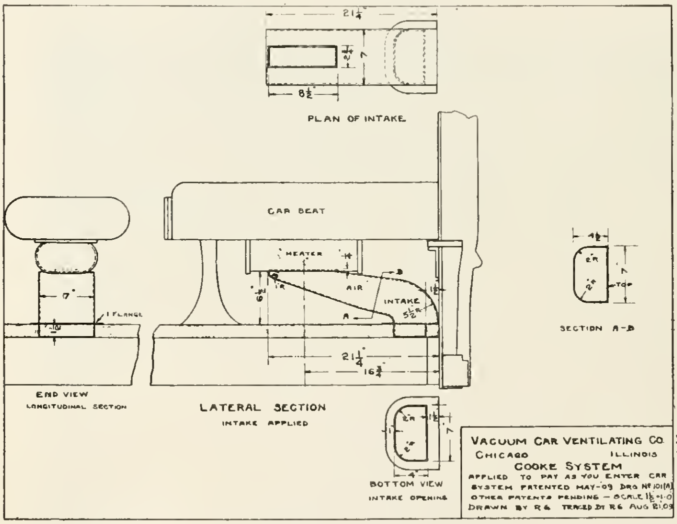

FIG. 3. AIR INTAKE.

service the average travel per car does not exceed 10 to 12 miles per hour, and the number of stops, especially in the congested districts, is relatively high. As a result of the conditions mentioned above, the showing made by some of the car ventilating devices tested was more or less unsatisfactory. In nearly every instance an attempt was made to exhaust the air through openings in the monitor deck by means of ducts or vanes which would provide a suction from the car interior due to the air velocity acting upon them when the car was in motion.

Means for the introduction of fresh air was provided at the floor level of the car, and connections were made to the electric heaters at or near the floor level of the car. Certain

of the fresh air openings were fitted with projecting arms, terminating in scoops, to assist the introduction of air through the car. The amount of air circulated through the car by means of the systems described above was found to vary with the velocity and motion of the cars in transit. A number of cars have been equipped and a careful record of the results obtained has been kept. A mechanical system of car ventilation designed to meet the requirements and conditions of the Chicago service has been designed and placed upon the market by the Vacuum Car Ventilating Company.

This system consists primarily in the application and use of an electric motor with a direct-connected exhaust fan. An exhaust chamber is formed in the monitor deck roof of the car, having two rows of circular register faces placed in the lower face and opening into the car interior. The exhaust fan and motor placed at one end of the vestibule roof of the car are connected with the exhaust chamber by means of a sheet metal housing with a cone connection. A series of fresh air intake connections are provided in the car floor and connected by means of steel ducts to the car heaters. When the exhaust fan is placed in service, a reduction of pressure is set up in the exhaust chamber, which induces a flow of air from the car body through each of the outlet registers in the lower side of this chamber. As the air is exhausted from the car body, a partial vacuum is produced throughout the entire interior of the car. This in turn induces a reduction of pressure at each of the fresh air intake openings, thereby providing for a circulation of heated air through the car body. This system may be designed to provide any given quantity of air required, and the air circulating through the car travels at such a velocity as to be imperceptible in its flow. The operation of this system is positive and is not affected by the movement, speed, direction of car or wind pressure on same. A continuous air change is provided, which insures perfect ventilation without any disagreeable draft of air. Three hundred and fifty cars are being equipped with this system, and will soon be in operation in the city of Chicago.

The developments of the past few years in the art of car ventilation are suggestive of the future progress in this direction. It is probably only a matter of a short time before legislation will be enacted to make improvements in this field compulsory, and certain scientific standards will be laid down, which will be followed and result in the greater safety and comfort of the traveling public.

THE HOME TRAVELING SCHOLARSHIP.

BY C. H. HAMMOND.*

So little is known by the main student body of Armour Institute of Technology, of the work and life of the young men who are toiling in the Department of Architecture at the Art Institute, that an article showing some of the work of this Department does not seem amiss in THE ARMOUR ENGINEER.

The senior and junior architects are just recovering from the effects of the Fourth Annual Traveling Scholarship Competition. Twenty-five very creditable sets of drawings were submitted, and finer spirit was never shown in the school than was shown by the men in the turning out of their work. It is unfortunate that space will not permit reproducing more of the drawings. However, the drawings shown, with the program and the criticism by Mr. Howard Van Doran Shaw, will give a good idea of the problem. A visit to the Art Institute will open the eyes of many to the earnest work of our young men who are striving to perfect themselves in the profession of Architecture.

It is assumed that the Institute owns the entire block bounded on the south by 33rd St., on the north by 32nd St., on the east by Dearborn St., and on the west by Armour Ave.

The main entrance, which is to be in a tower, will be on 33rd St., or on the corner nearest the present buildings.

The style of architecture to be used is left to the designer, as the present style need not be followed.

The balance of the block not occupied by the Commons will be used for athletic field and gymnasium.

Requirements:

Entrance Tower.

College Hall or dining room, which will also be used for college dances, etc. Hall must be large enough to seat easliy 350 men at long tables. Kitchen and pantries may be located in basement.

(2) check room suites with retiring and toilet rooms.

Billiard room, six tables.

(4) Club rooms. To be used for Technical Clubs, Atelier, Fulcrum and class officers, approximately 400 square feet each.

(3) Bowling alleys—may be in basement.

(2) Shower baths—may be in basement.

Toilets.

Library to accommodate 30,000 volumes and 3,500 pamphlets.

Stacks to be used.

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*Class 1904, Assistant Professor of Architecture, Armour Institute of Technology.

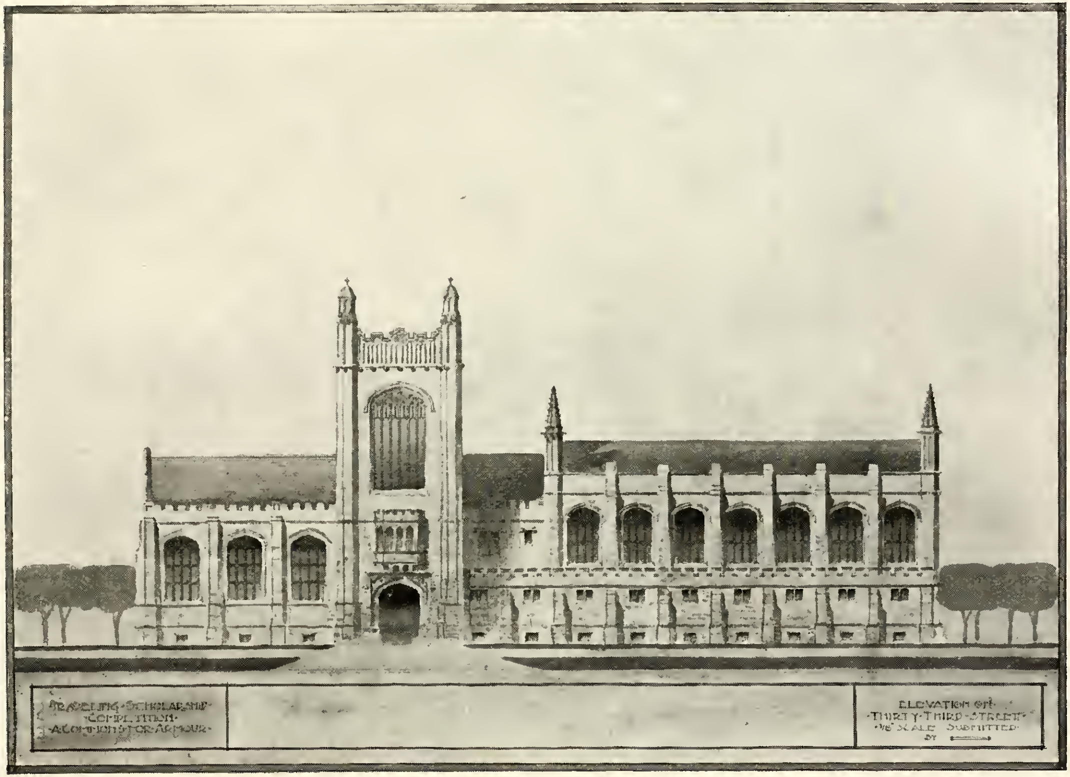

FIG. 1—ELEVATION. FIRST PRIZE.

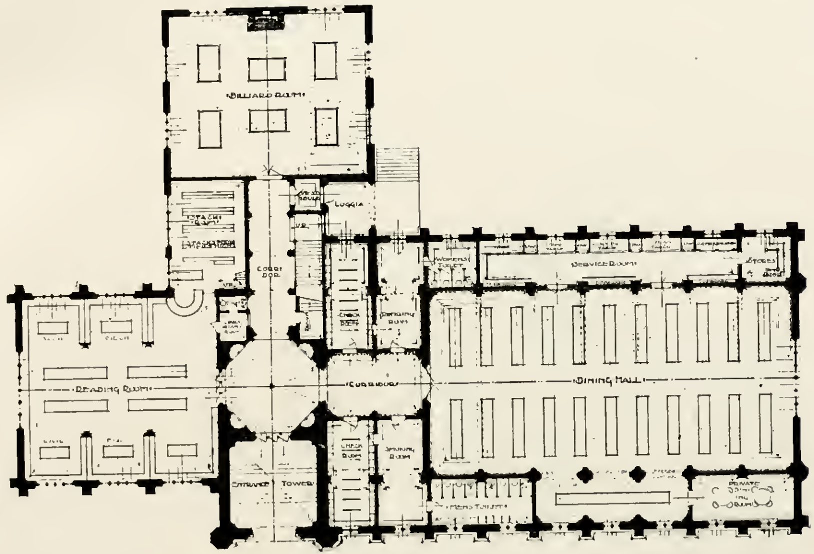

FIG. 2—PLAN. FIRST PRIZE.

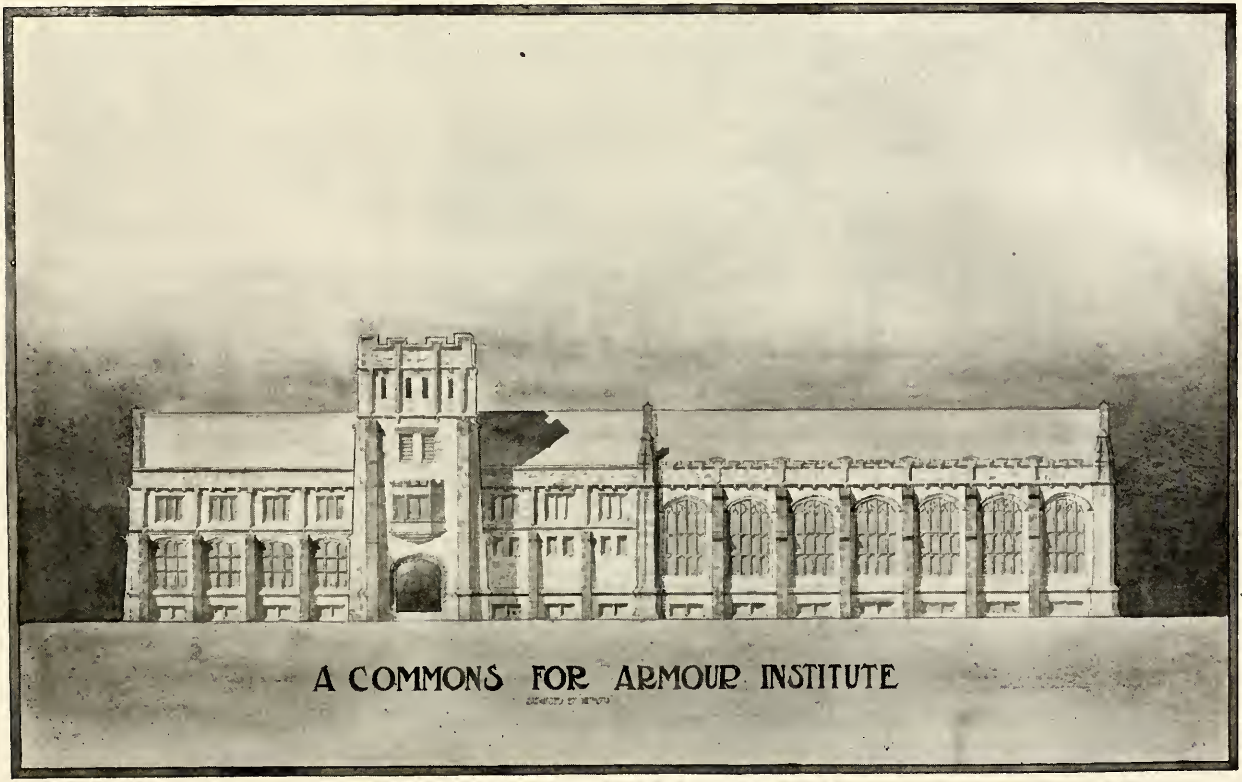

FIG. 3—ELEVATION. SECOND PRIZE.

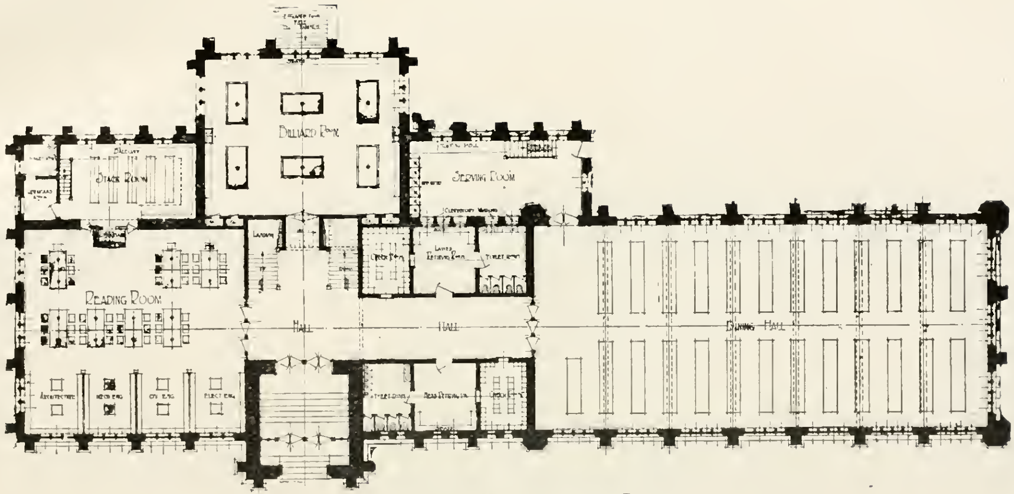

Fig. 4—Plan. Second Prize.

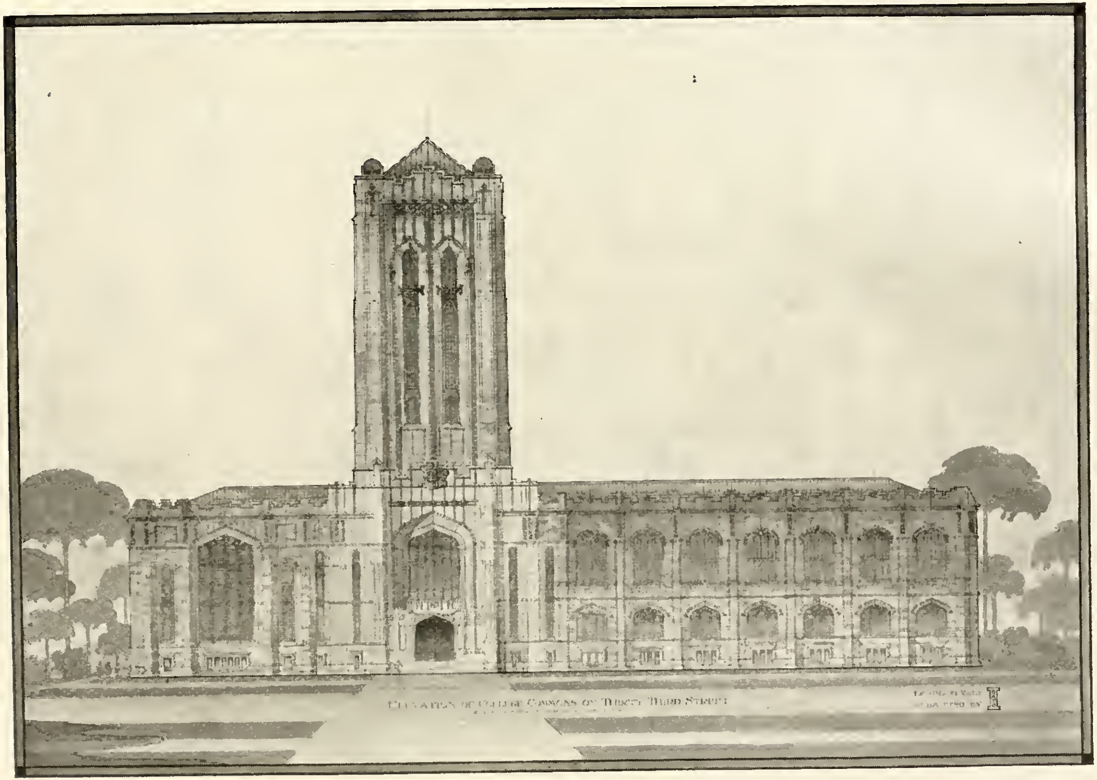

Fig. 5—Elevation. Third Prize.

Reading room with separate alcoves for reference books on architecture, electrical, mechanical and civil engineering.

Approximate area of reading room 1,200 sq. ft.

2nd Floor.

Lounging room for professors, toilet.

(2) bedrooms, each with closet and bathroom, for professors in charge of Commons.

Club rooms before mentioned may, if desired, be placed on the second floor.

Drawings required.

Plat showing location of proposed buildings, athletic field and gymnasium.

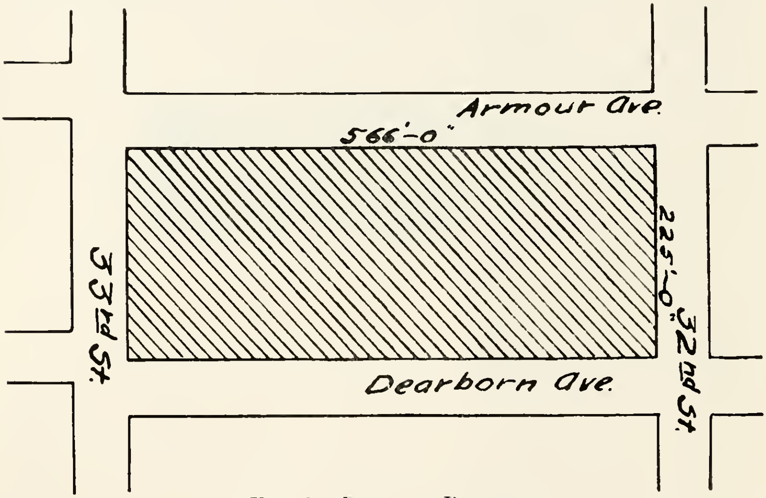

FIG. 6. PLAN OF BLOCK.

Scale 1/32"—1'-0".

(Note) (2nd floor plan shown on plat.)

Elevation on 33rd St. and cross section at a point selected by the designer to obtain the best effect. Scale 1/8"—1'-0".

Plan 1st floor, 1/8"—1'-0".

Interior of perspective of Dining Hall at 1/4"—1'-0".

Detail of Tower. Scale 1/2"—1'-0".

Note.—All drawings with the exception of the Tower detail to be rendered in color.

Tower to be line drawing in pen and ink.

Criticism.

April 15th, 1910.

Dear Mr. Shattuck:—

I have the honor to report my findings as follows, in the $250.00 Home Traveling Scholarship Competition.

First place is given to Drawing No. 15 (Mr. Karl F. Saam).

In general treatment this design follows more closely than any other the best English precedent in proportion, fenestration, roof treatment, scale of relative parts, and has a very Gothic feeling inside and out, and though in an archaic style is alive. The plan is scholarly, and the best exhibited both architecturally and scholarly. It would be a credit to the best office.

The axes of the building are the proper axes of the three great rooms, each room is entered at the best point. All rooms are well proportioned, and with the exception of the librarian's room, well lighted. There is a minimum of corridor and waste space. The windows of the dining hall are skillfully proportioned, and located as well inside as out, not an easy task. The roof trusses would be monotonous and tiresome with so many small members. The stairway leading to the unimportant second story is duly repressed.

The large tower shows a limited knowledge of Gothic details, not uncommon in the west, particularly in the window tracery and in the scale of mouldings, and of the traceried panelling under the battlements. The tops of the corner tourelles of the tower wander from the best Gothic, though they would make a pleasant silhouette against the sky. The type of vaulting in the vestibule and octagonal hall could be improved. The niche treatment is weak. The drawings are reasonably well rendered. The sole criticism might perhaps be that there is too close an adherence to well-known examples of this type.

The second place is given Drawing No. 14 (Mr. Harry I. Dalsey).

A rather simpler, more restful paraphrase of the design given first place. The treatment is more amateurish and the rendering weak; but the good points are well brought out. The plan lacks little of the merit of No. 15; the service department of the dining hall is not nearly so good; the stack and librarian's room much better. The entrance from the field through the basement is not so good as the loggia of No. 15. The exterior is well proportioned and restful, though the batter on the buttresses is questionable, and might better have been done by successive offsets.

The tower detail and section show inexperience. The dining hall, less lofty than No. 15, and with the windows placed

nearer the floor, is more domestic and would possibly lack impressive dignity. The trusses are interesting and well proportioned.

Design No. 4 is placed third (R. S. Frodin).

This is the best rendered design, and would produce, if constructed, an imposing building. The plan is ingenious, practical and cleverly worked out in detail. The faults are the poorly proportioned fenestration, the excessive loads on the clustered columns of the dining hall, which, though possible, would offend the eye, and the atrocious curve and stone jointing of the Tudor arches.

Many of the defects of the design are concealed by clever rendering and only appear on analysis. The sections, particularly the billiard room, are excellent.

Honorable Mention is given No. 13 (Mr. E. S. Pashley).

For an admirable tower, the excellent relation of the masses, and clever relative quantities and disposition of brick and stone. The heavy pier treatment of the end pavilions puts them in a different style from the tower, and this could have easily been avoided. The plan is bad, not a single large room is properly on aixs; the corridor axis if continued (this is the line of vision of every one entering the rooms) strikes a bookcase end or unimportant pier.

I take pleasure in calling attention to the individuality and charm of the perspective of college hall in design No. 8 (Mr. Ralph E. Smalley). Unfortunately the author got beyond his depth on the exterior.

A general criticism of many of the designs would be that of too monumental a scheme inadequately treated.

Very truly yours,

(Signed) HOWARD SHAW.

ELECTROLYTIC CORROSION AND DETERIORATION OF UNDERGROUND METALS.

A Junior Thesis Presented to the Electrical Department.

BY W. P. McGUIRE.*

Investigations from time to time into the results of electrolytic action due to stray currents from railways have disclosed water mains, gas mains and telephone cables in many cities of the country to have been rendered useless by such action. Within the last five years the leading gas companies of the United States have maintained a special staff for such investigation and to seek experimentally means of combating the destructive effects of electrolysis. Few remedies have as yet been tried with any degree of success. Bonding of rails and better insulation of joints of pipes are now receiving great attention. Numerous preparations for wrought iron service pipes have also met with approval. Recently the Street Railway Companies of Chicago, in reconstructing their lines laid their tracks upon a bed of concrete both for stability and as a preventive for electrolysis which was recommended by a committee of engineers of the Illinois Gas Association. Whether such protection is reliable remains to be seen. A subsequent test made by The People's Gas Light & Coke Co. at their works at Pitney Court during the past summer and winter and still being carried on, has so far shown evidence adverse to the use of concrete as a remedy. In the meantime public service pipes of all kinds must continue to be replaced at frequent intervals.

The damage to underground steel structure of buildings by electrolysis is very difficult to discover on account of the inaccessability of the sub-structure. However it would seem that this is most certainly a grave possibility with results too awful to foretell. It may be that after some great calamity or upon the reconstruction of some of the earlier buildings that some exceedingly valuable data will be obtained therefrom.

A full comprehension of the cause of electrolysis involves only an understanding of the nature of the action of the simple electrolytic cell or of the electroplating bath. In the latter case the current which enters the solution through the silver or other suspended metal flows through the bath to the object to be plated and out again through the external circuit. Ultimately the suspended strip of metal, which is the positive electrode, is destroyed. In a similar way on a trolley line the current flows from the trolley wire, which is the positive side through the cars to the rail and from there it has two paths back to the power station. Obviously the current will select the path offering the least resistance. This, theorectically, should be the rails, and they should therefore, necessarily be

*Class 1911, Armour Institute of Technology.

well bonded. Usually, however, the current divides, inversely as the resistances of the respective paths a part returning on the rails and the remainder on the water or gas mains which parallel the road. Figure 1, indicates the course of the current in the line and back to the generator. The current passes out from the station through the trolley and the car motors to the rails and thence back to the station generator by the various paths shown by arrows.

The damage wrought is always at the point where the current leaves the pipes and hence great trouble is usually experienced near generating stations. The return current may enter the station directly from the pipe or it may jump back again to the rail and return thus. The latter is very often found to be the case since the rails are usually well bonded near such points. The current does not always flow along a single pipe to its destination, but in any locality where the soil is suitable it may jump say from a water pipe to a gas main paralleling the water pipe, across to a telephone conduit

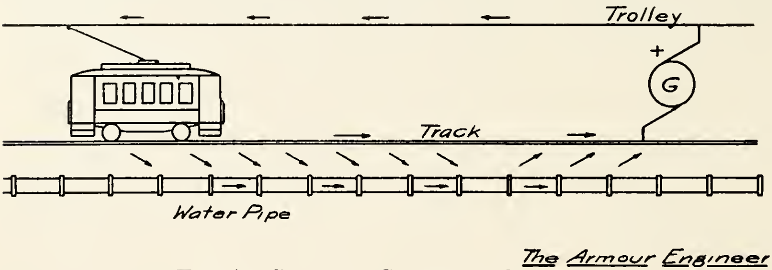

Fig. 1. Showing Course of Current.

casing and back again to the rail farther on. The magnitude of the injury is thus greatly augmented since at every point on each of the several pipes and cables mentioned where the current leaves the metal, damage is inflicted.

At such point where the current leaves the pipe for any reason, hollow or soft places are left in the metal, and the iron thus removed is deposited as pittings. The pittings under continued action rapidly increase in size until large holes may in time be formed in the pipe. Unless they are washed away by the actual bursting of the pipe the deposits or pittings remain in the hole where they are formed and may be taken out when the main is removed. Pittings are very light in weight and vary in color. They contain much carbon and other foreign material which often falls away when the substance is dried.

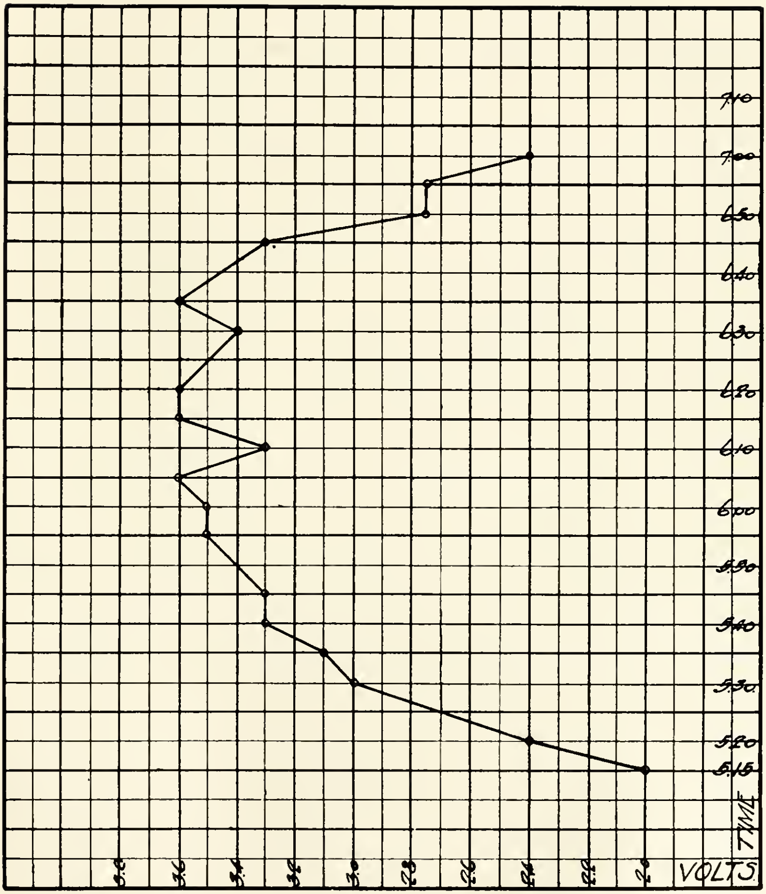

FIG. 2. DIAGRAM SHOWING POTENTIAL VARIATION BETWEEN BROOKLYN BRIDGE AND WATER MAINS ON MANHATTAN SIDE.

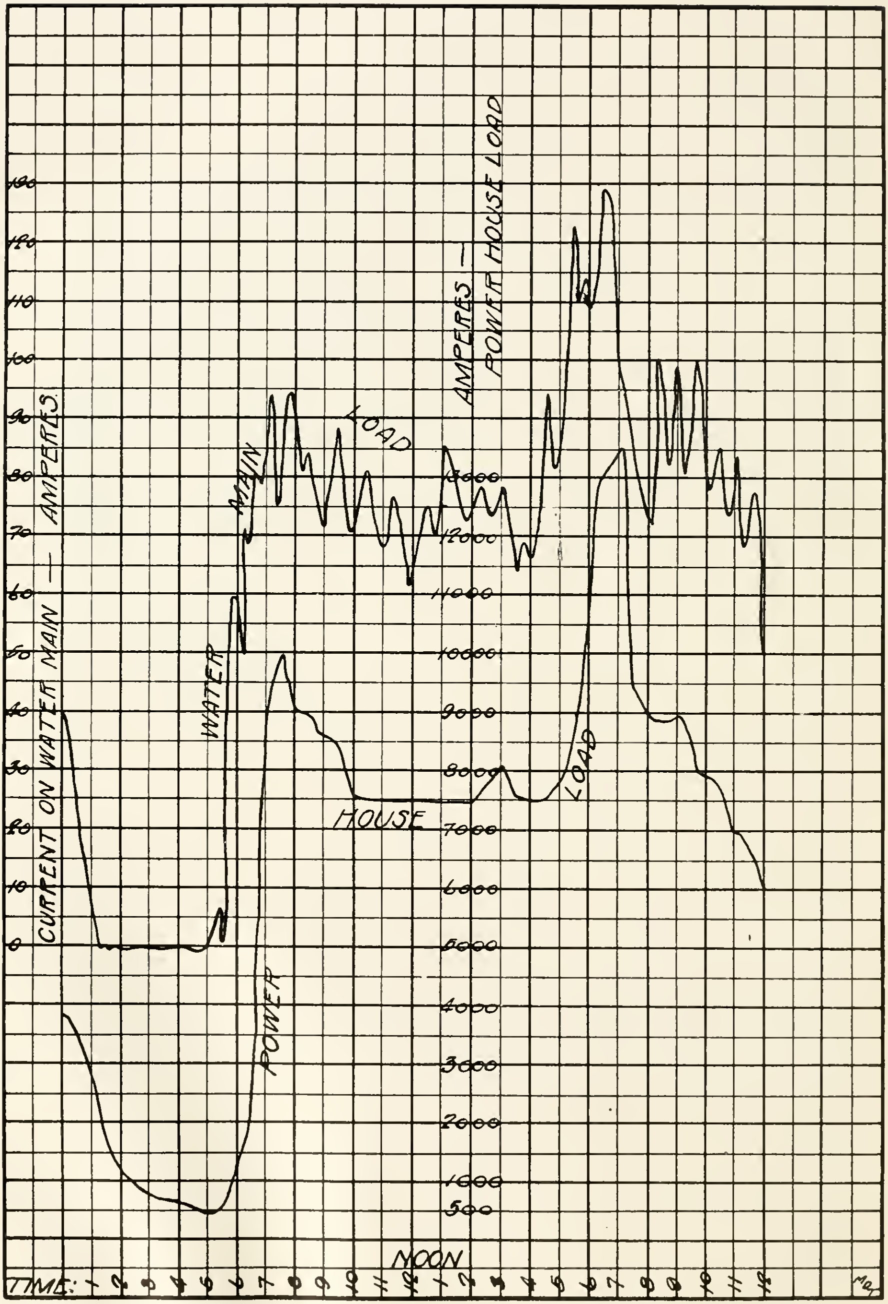

FIG. 3. COMPARISON CURVES. SHOWING CURRENT VARIATIONS ON 36″ WATER MAINS FOR 24 HOURS, AND ALSO POWER STATION LOAD FOR 24 HOURS, ENDING MIDNIGHT.

Nearly all soils contain sufficient salts to readily form the necessary electrolyte to conduct the current between the rail and pipes. The alkali salts are the most active. They are present in the soils of all cities in large quantities. Places filled in with cinders and refuse are especially bad electrolytically. Damp spots furnish more moisture for a solution of the salt and hence low places are also particularly susceptible to electrolytic action.

A study of soil conditions and the tracing of underground circuits has often suggested valuable remedies for existing electrolytic action. A. A. Knudson, E. E., has made extensive observations in New York in the vicinity of Brooklyn Bridge.* Much current flows from a power station on the Brooklyn side over the Brooklyn Bridge to Manhattan, thence through the various underground pipes and across the Williamsburg Bridge returning to the power station again through the underground mains of Brooklyn. All along this path the current is continually being augmented by currents from nearby rails. A. A. Knudson states that previous to the building of the Williamsburg Bridge the currents spread over an area as far north as Twenty-third Street (about two miles) before they crossed back to the Brooklyn side through the river bed. A test made on the Brooklyn side of the bridge shows a maximum of nearly seventy amperes on a six inch water main near the power house. Further tests made by Knudson in May, 1902, between five and seven P. M., namely during the rush hour period, showed conclusively the source of the existing underground currents. A potential test was made with a Weston voltmeter by connecting the leads so that the Brooklyn Bridge was positive to the water mains on the New York side. The current was coming from Brooklyn. The instrument registered two volts at five P. M. and reached a maximum of 3.6 volts between 6 and 6:35 P. M., falling off to 2.44 volts at 7 P. M. The curve (See Fig. 2) shows the variation in voltage for each five minutes. This curve would tend to show that the railways were responsible for the current on the mains. Conclusive evidence might be had from curves similar to those shown in Figure 3. These curves show the load line for a period of twenty-four hours of a power house and also the current on a 36-inch water main nearby. The readings were taken simultaneously. The way that the water pipe curve reflects the conditions of load at the power station is very striking. Both of these curves (Fig. 2 and3) may be taken as representative conditions in all cities of the United States where electric railways exist with ground returns.

*See Journal of Franklin Institute, August, 1909.

A curious case in England was cited by Henry Bassett, Jr., E. E.* He investigated a leak in a 460 volt underground power cable which had become noticeable owing to the fact that horses became restive at the spot from shocks they received. He stated that the current was carried by copper cables and that these cables were laid in solid bitumen which was placed in a trough buried in porous sandstone. Only the negative cable seemed to be affected (its potential being 230 volts below that of the earth) and it had previously been jointed at the point of leakage. The wooden trough mentioned had been burned through and a solid formation of sodium potassium hydroxide formed about the joint. This compound was extremely hard and contained in its interior globules of metallic sodium and potassium. This fact lead Mr. Basset to advance the belief that such electrolytic formations of alkali metals might react with water in confined places and cause dangerous explosions. Engineers in general have refuted this point on the ground that the Hydrogen formed would not be great enough to cause such a result.

Many instances have been noted where switches which have fastened to concrete or stone walls in low basements have received a coating of potassium sodium carbonate. A particular case was mentioned by Prof. Marchant at the University of Liverpool. The switch in question was placed on a concrete wall, the wall being tarred on the outside. As usual the negative side only was affected. The explanation was advanced that owing to electric endosmose moisture was driven from the positive to the negative side. This explanation would show a similarity to the rise of the liquid around the cathode in a simple electrolytic cell. If these things be true much of the failure of insulation of the negative wire in D. C. work might be accounted for. Thus the insulation of the positive side would tend to improve and the negative side to break down or deteriorate from alkaline or other foreign deposits.

Of the different materials in general use, underground, lead is the most seriously affected electrolytically if unprotected. Telephone cables are usually enclosed in lead casings which are laid in glazed tile conduit pipes which beyond doubt protects the lead to a great degree. Telephone conduits are as yet not near so numerous in the streets of our large cities as other public service pipes, and so electrolysis in that direction has not received as much attention as in the case of water and gas pipes where leaks quickly manifest themselves, especially in the case of gas mains, where even a small leak is almost immediately detected.

With steel and wrought iron the greatest danger is apparent although in many cases cast iron is very seriously

*See Lond. Elect., April 12, 1907.

affected. C. F. Burgess has made exhaustive tests of the electrolytic corrosion of different grades of iron and steel after first being subjected to various conditions of strain.* From his results he deduced the rule that the corrosion was nearly directly proportional to the amount of strain. This might explain the fact that sometimes the fittings (malleable iron) attached to service pipes have their threads eaten almost entirely away, when at the same time their outer surface shows little affect from such action. It would be due to the strained condition of the thread produced in manufacture.

Some idea of the susceptability of wrought iron or mild steel pipes to electrolysis may be obtained from the fact that in some places in Chicago the People's Gas Light & Coke Co. still find it necessary to replace service gas pipes of such material every six or eight months. The electrolysis staff of that company has formulated a compound which now seems to be very effective and which they place on all service pipes. The preparation is a special form of the more general type of preventive called Cremo. I found them reticent in giving out its exact ingredients.

Robert B. Harper in his report to the Illinois Gas Association on March 18th, 1909, gave the following as the general recipe for Cremo:

"A fifty gallon barrel of clean water-free coal tar, is placed in an ordinary portable tar kettle and gradually heated up by a slow fire. When sufficiently fluid twenty-five pounds of freshly slaked lime are sifted over the top and well stirred into the tar which is now brought to a boil. When the mixture shows a consistency of a soft pitch upon cooling a sample to ordinary temperature, the fire is drawn and the whole allowed to cool somewhat. The maximum temperature of the mixture when the fires are drawn is usually 500 degrees F. The hot pitch is transferred to settling and cooling tanks. As the mixture cools to about 350 degrees F. three pounds of powdered resin and about eight pounds of tallow are added and worked in until well dissolved and incorporated with the pitch. When a temperature of about 200 degrees F. is reached five gallons of rubber cement (containing rubber and turpentine in the ratio of four pounds of pure rubber to seven gallons of turpentine) are added and stirred in until a thoroughly homogeneous mixture results."

Cremo when fresh is a brownish black soft material that possesses tenacity and when stretched by pulling apart two surfaces to which it is attached, presents a fibrous or ropy appearance. Even when made with the greatest care it contains particules of rubber which appear as minute lumps. It has a

*See Electrical Review, Sept. 19, 1908.

specific gravity of from 1.2 to 1.25 and often contains over 3% by weight of lime. It becomes fluid at about 80 degrees F. It remains soft for a considerable time but gradually hardens apparently by volatilization and oxidation of some of its constituents.

The Cremo is placed on the pipes in connection with tarred tape before they leave the shop and they are recoated after laying to take care of any removal of the compound by wrenches while handling. Many other preparations have been used extensively. Tar coating mixture has been much used by the Consolidated Gas, Electric Light & Power Co. of Baltimore. It contains:

10 gallons of coal tar.
18 gallons of oil tar.
7 quarts of turpentine and crude rubber mixture.
5 pounds of dissolved tallow.
1¼ pounds of resin.

The whole is heated and applied with a brush when cold, (Spec. Grav. 1.146).

Various mixtures are marketed by manufacturers under trade names. A few are mentioned in Table 1 as given by R. B. Harper from his investigation of each mixture, using twelve different samples of each.

The theory of all of these coatings for the proper protection of underground pipes is based upon the fact that a current which leaves a metallic surface by way of a conductive medium such as a paint or covering that is non-ionizable, will produce no electrolytic effect upon that surface. Graphite paints make good conductive mediums to be placed between the sub-metallic structure and the soil. Such paints must also act as a barrier between the metallic surface and the soil, to the products of dissociation if there be any such products. Many substances such as pulverized chalk, anthracite coal and gelatined silica compounds when applied too thick or in the presence of moisture lose much of their efficiency. Again, many of these materials are destroyed by nascent chlorine, which is often given off by electrolytic action. For this reason electro-positive elements such as lead, iron and aluminum should not be used in coatings. Any impurity of iron in a graphite paint would readily be extracted electrolytically and the surface of the paint thus broken would allow the metal surface to be directly exposed.

Coal tar from which all metals have been removed, when mixed with dry sand has been found to be a good coating. It is sometimes used in connection with a cloth covering. Cloth coverings are in general prohibitive however, because of ex-

pense in the cost of the material and its application. Again it does not allow an intimate enough contact with the metal and thus moisture may get under it. Cement is uncertain and has been much condemned. It is partially conductive and when applied with sand has provided good protection. In most cases however it is found that water will get in between the metal and the cement layer and cause rapid corrosion.

Much has been said on the subject of Alternating Current electrolysis and some engineers have even stated it to be negligible. However it now seems to be commonly acknowledged that alternating current electrolysis is becoming more and more a factor and its effects are about one half as disastrous as those in D. C. work since the current is flowing only

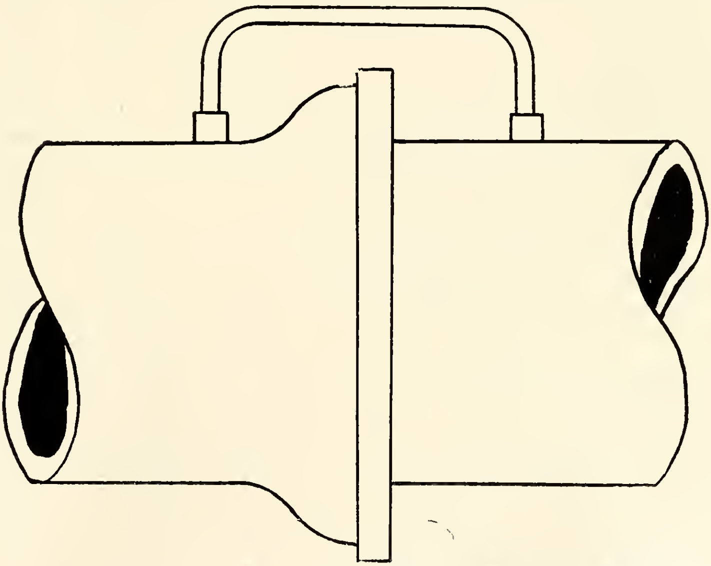

Fig. 4. Showing Method of Bonding Commonly Employed.

one half of the time in a given direction. Serious alternating current conditions have not very often been encountered since A. C. has not as yet come into general use in street railway service, but there is no doubt that when it is used more serious complications will arise. For the present the argument and remedies given in this paper will apply to most cases of A. C. Electrolysis.

In this discussion I have tried to dwell chiefly on those methods of protection upon which electrolysis experts are at the present day working. A summary of all the various methods and remedies in practical use would show the scope

Sample	Kind of Coating	Number of Coats Applied	Temp of Application in Degrees F.	Average Thickness of Protective Film in inches
1	Cremo	1	180	.008
2	Annapolis Mixture	2	70	.006
3	Dr. Angus Smith's Mixture	1	200	.008
4	Red Lead Paint	4	70	.005
5	Sarco Pipe Dip	1	400	.0035
6	Concrete	1	70	.500
7	Ebonite	2	70	.001
8	Carbonkote No. 1	2	70	.0015
9	Crysolite	2	70	.0045
10	Voltax	2	70	.0025
11	Acid Fume Proof Paint	2	70	.0025
12	Depews No. 1	2	70	.002
13	Hogul Electrical Compound	2	70	.0035
14	Mogul Repairing Compound	2	70	.0085
15	Carbonkote No. 100	2	70	.002
16	Ohmlac No. 1	2	70	.0015
17	Tar Coating Mixture	2	70	.0015
18	Sarco Cold Field Coating	2	70	.004
19	Sarco R. R. Special Coating	2	70	.005
20	Ohmlac K-35	1	275	.007
21	Black Monarch Dip	1	240	.014
22	Red Monarch Dip	1	270	.022
23	Cleafite	1	300	.005
24	Cremo Pitch	1	180	.095
25	Water Gas Tar Pitch	1	180	.055
26	Cremo No. 2	1	180	.013
27	Resistance Pipe Coating	1	300	.0105
28	St. Louis Mixture	1	150	.019
29	Cremo No. 3	1	180	.013
30	Cremo No. 4	1	180	.011
31	Texaco	1	350	.009
32	Coal Tar Pitch 600° F.	1	200	.018
33	Coal Tar Pitch 700° F.	1	250	.016
35	Water Gas Tar Pitch 700° F.	1	200	.003
36	Mineral Rubber Pipe Dip 250° F.	1	275	.016
37	California Refined Asphaltum	1	300	.0075

of this subject and the possibilities of investigation along other lines. I will only enumerate these branches of the subject.

An infallible remedy for electrolysis would be the installation of all street railways with a double trolley system.

Such a method is however out of the question at present. It has been estimated that a complete reconstruction along such lines would involve an expenditure of over $200,000,000 in the United States.

Insulated pipe joints alone, are practically useless because they only cause further electrolysis at the bell or spigot end of the pipe.

To coat all piping lines with a non-ionizable material would involve an enormous cost. The various paints and coverings in use and their relative value may be estimated from Table 1.

Negative Boosters have been tried for the purpose of sending counter currents against the natural flow of the earth currents to neutralize the latter. They are objectionable because of the cost of maintenance.

Some companies have adopted the scheme of reversing the polarity of the line every twenty-four hours thus making the rails positive one day and negative the next. Such a system has also been condemned on the ground that it seems to scatter the destructive effect over a larger area of pipe line instead of localizing.

In England and in some parts of Germany a seven volt rule has been made law. Seven volts is the maximum drop allowed by law between any two points on the track. It increases the efficiency of the return circuit and reduces electrolytic action considerably.

A combination of good uniform rail bonding together with a low drop over the track seems to be highly recommended. The pipes should also be heavily bonded to each other with copper. The negative bus bar in the power house should be connected to the bonded mains at frequent intervals by a large copper return pipe so as to reduce the current flowing over the mains to a minimum at any one point.

A TEST OF SLENDER WOODEN STRUTS FOR AEROPLANES.

BY M. A. SMITH.*

The recent progress in aviation with so-called "heavier than air" machines, has attracted much popular and scientific attention. From the viewpoint of the engineer the question at once arises, are these machines correctly and safely designed to resist the strains to which they are subjected? Conversations between engineers and some of the most prominent of the aviators and aeroplane builders disclose the fact that for the most part, aviators are so wrapped up in the possibilities of human flight that their designs as far as structural safety goes, have been on the "rule 'o thumb" principle. The writer does not mean to imply that "light gas engines" are to be included under "structures," for some of the greatest engineers have, and are now, putting forth their best efforts toward the design of suitable power plants for air vehicles. By structures we mean the planes or aerofoils themselves, and their bracing and alighting gear.

An examination of the sizes of the wooden struts or columns which are used in the alighting gear and between the planes in a biplane or multiplane machine will result in some rather remarkable engineering data. The writer, together with W. A. Stevens and W. A. Kellner, is at present engaged in conducting a test of these slender struts. Measurements of the length and cross-section of struts found in successful aeroplanes were obtained, and the slenderness ratio, i. e. the length in inches divided by the least radius of gyration, calculated and tabulated. The table yielded some rather interesting results.

In the landing gear of the Wright aeroplane, there is a strut which has a slenderness ratio of something like 380. The struts between the planes of successful biplanes show slenderness ratios of between 220 and 200. Obviously, the straight line formula of Rankine will not apply in the design of these columns; but even Euler's formula, which practice in steel and iron would indicate as the correct one to apply, gives results so small as to preclude its use without modifications. The fact remains, however, that these struts are in use and have but few, if indeed any, failures recorded against them.

A series of test was therefore undertaken to determine if possible, how much load these slender wooden struts would safely hold. The first step was to prepare a table of lengths and dimensions of columns so designed that the slenderness ratio would vary from 100 to 400. Specimens were then made

*Class 1910, Civil Engineering, Armour Institute of Technology.

of good clear spruce (which at present seems to be the material most favored by aviators), to these dimensions. Four columns of each type were made, two being intended for use with round ends, and two with fixed ends. At the present time, all but one of the fixed end columns have been broken, and while it is yet too early to give definite results, the disagreement of the ultimate strength as calculated and as determined experimentally, has entirely justified the experiments.

To cite examples: columns calculated to hold but twenty-eight pounds successfully, held 250 pounds; those calculated to hold 625 pounds held 1,500 and 2,000 pounds respectively; while another pair, which by Euler's formula should have withstood 1,600 pounds, held but 896 and 936 pounds, respectively.

The experimenters hope to be able from their final results to at least secure some stable basis on which the design of wooden struts for aeroplanes may be founded.